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THE PURPOSES OF THE TASK 4 WATER SURVEY ARE TO 1) EXECUTE A ONE YEAR GROUND AND SURFACE WATER SURVEILLANCE PROGRAM CAPABLE OF SATISFYING THE VARIOUS REGULATORY REQUIREMENTS, 2) DEVELOP A LITIGATION QUALITY DATABASE, AND 3) VERIFY THE EXTENT AND NATURE OF KNOWN CONTAMINATION. THE TECHNICAL ELEMENTS OF THIS SURVEY ARE: 1) REVIEW HISTORICAL DATA, 2) DEVELOP A MONITORING PROGRAM, 3) EXECUTE THE MONITORING PROGRAM, 4) ASSESS THE DATA QUARTERLY FOR POSSIBLE ADJUSTMENTS, 5) COMPILE THE DATA AT THE END OF THE PROGRAM.

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LITIGATION TECHNICAL SUPPORT AND SERVICES

ROCKY MOUNTAIN ARSENAL

WATER QUANTITY/QUALITY SURVEY

FINAL TECHNICAL PLAN

FILE COPY

TASK NUMBER 4

SEPTEMBER 1986

ENVIRONMENTAL SCIENCE AND ENGINEERING

USATHAMA

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US ARMY

PROGRAM MANAGER'S OFFICE FOR

ROCKY MOUNTAIN ARSENAL

LITIGATION TECHNICAL SUPPORT AND SERVICES

Rocky Mountain Arsenal

Water Quantity/Quality Survey

Final Technical Plan

September 1986
Contract Number DAAK11-84-D-0016
Task Number 4

PREPARED BY

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.
Harding Lawson Associates
Resource Consultants, Inc.

PREPARED FOR

U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY

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LIST OF ACRONYMS AND ABBREVIATIONS
(Page 1 of 2)

AMC	U.S. Army Material Command
AR	Army Regulation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CDRL	Contract Requirements Lists
CFI	Colorado Fuel and Iron Corporation
cm	centimeters
cm/sec	centimeters-per-second
COR	Contracting Officer's Representative
DBCP	dibromochloropropane
DCPD	dicyclopentadiene
DDT	dichlorodiphenyltrichloroethane
DIMP	diisopropylmethylphosphonate
DMMP	dimethylmethylphosphonate
ESE	Environmental Science and Engineering, Inc.
ft	feet
gpd/ft	gallons-per-day feet
ha	hectares
HLA	Harding Lawson Associates, Inc.
IC	Irondale System
in	inches

LIST OF ACRONYMS AND ABBREVIATIONS
(Page 2 of 2)

IR-DMS	Installation Restoration Data Management System
km	kilometers
m	meters
MRI	Midwest Research Institute
NBC	North Boundary Control System
NWBC	Northwest Boundary Control System
NWS	National Weather Service
OSHA	Occupational Safety and Health Act
QA	Quality Assurance
QC	Quality Control
RCI	Resource Consultants, Inc.
RCRA	Resource Conservation and Recovery Act
RIC	Rocky Mountain Arsenal Resource Information Center
RMA	Rocky Mountain Arsenal
Shell	Shell Chemical Company
STP	Sewage Treatment Plant
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
HCCPD	hexachlorocyclopentadiene
GC/MS	gas chromatography/mass spectrometry
WBS	Work Breakdown Structure

1.0 INTRODUCTION

1.1 DESCRIPTION OF THE RMA PROBLEM

The Rocky Mountain Arsenal (RMA) occupies over 27 square miles (sq mi) in Adams County, Colorado, and is located approximately 9 miles (mi) northeast of downtown Denver (Figure 1.1-1). RMA was established for the manufacture of chemical and incendiary munitions and for demilitarization of chemical ordnance. Industrial chemicals were manufactured at RMA from 1947 to 1982.

The property occupied by RMA was purchased by the government in 1942. Throughout World War II (WWII), RMA manufactured and assembled chemical intermediate, toxic end-item products, and incendiary munitions.

During the period 1945 to 1950, RMA distilled stocks of Levinstein mustard, demilitarized several million rounds of mustard-filled shells, and test-fired 10.7 centimeter (cm) mortar rounds filled with smoke and high explosives. Also, many different types of obsolete WWII ordinance were destroyed by detonation or burning.

In 1947, certain portions of RMA were leased to the Colorado Fuel and Iron Corporation (CF&I) for chemical manufacturing. CF&I manufactured chlorinated benzenes and dichlorodiphenyltrichloroethane (DDT). Julius Hyman and Company assumed the CF&I lease in 1950 and Hyman produced several pesticides. Shell Chemical Company (Shell) later assumed the pesticide and herbicide manufacturing operations.

In the early 1950's RMA was selected as the site for construction of a facility to produce chemical agent. The facility was completed in 1953, with manufacturing operations continuing until 1957, and munitions filling operations continuing until late 1969. Since 1970, RMA has been involved primarily with the disposal of chemical warfare material.

Disposal practices at RMA have included routine discharge of industrial waste effluents to unlined evaporation basins and burial of solid wastes at various locations. In addition, unintentional spills of raw

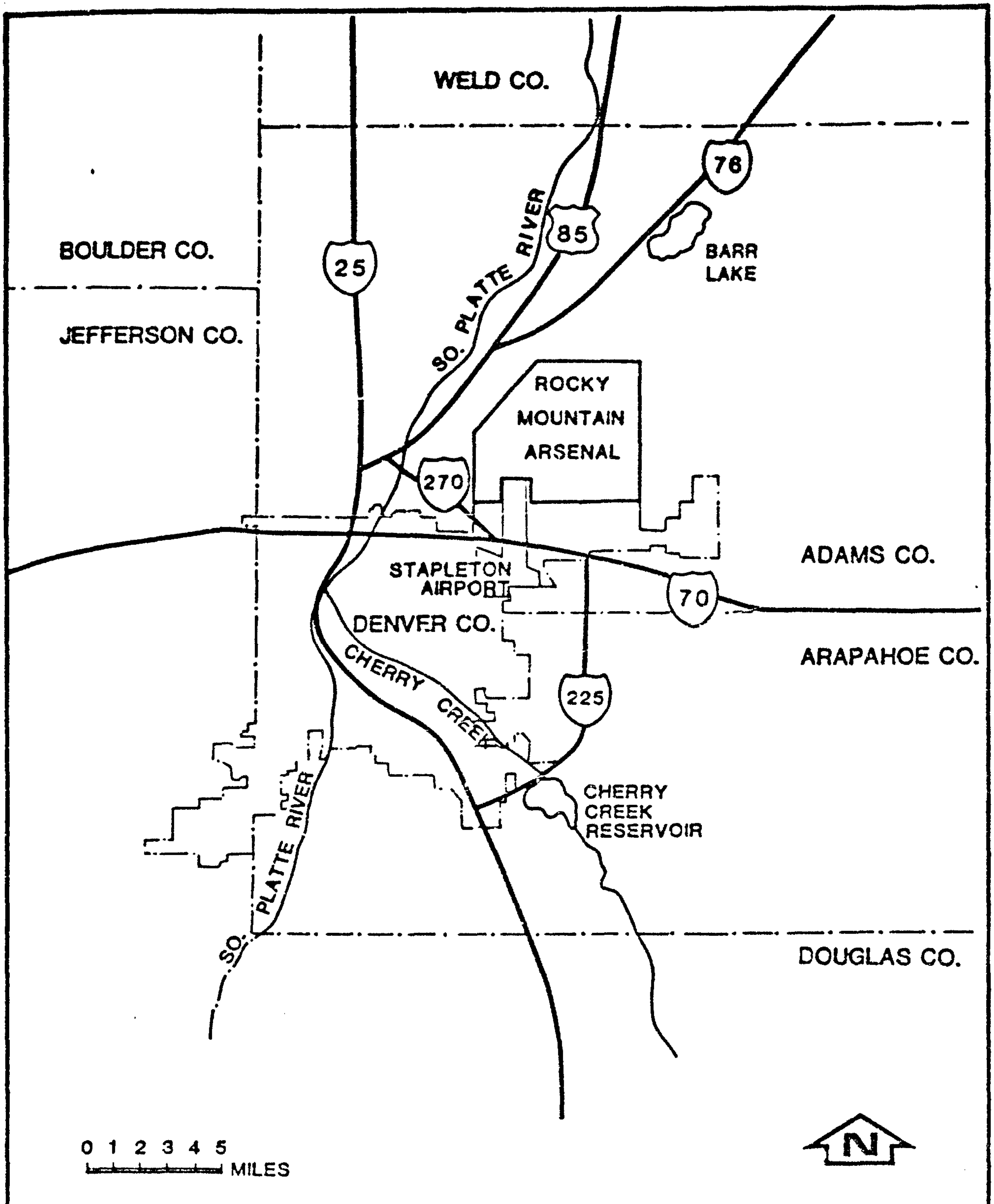


Figure 1.1-1 ROCKY MOUNTAIN ARSENAL LOCATION MAP	Prepared for: U.S. Army Program Manager's Office For Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland

materials, process intermediates, and end products have occurred within the manufacturing complexes at RMA. Many of the compounds are mobile in surface and ground waters.

In 1954 and 1955, farmers to the northwest of RMA reported severe crop losses due to use of well water for irrigation. In 1974 two contaminants, diisopropylmethylphosphonate (DIMP), which is a by-product of the manufacture of GB nerve agent, and dicyclopentadiene (DCPD), a chemical used in insecticide production, were detected in offpost surface water. Since 1978, offpost migration of dibromochloropropane (DBCP), a nematocide which had been shipped from RMA by rail from 1970 to 1975, has been observed in ground water.

In response to the detection of offsite contamination migration, the State of Colorado issued a Cease and Desist Order in 1975 which required RMA to initiate a regional hydrologic surveillance program. The program required the quarterly collection and analyses of over 100 onpost/offpost surface and ground water samples. In addition, various other programs have been implemented and are utilized for monitoring and surveillance of ground and surface water in order to satisfy operational and other regulatory requirements at RMA.

As part of the investigation of environmental conditions present at RMA, the necessity to establish a litigation quality data base for surface and ground water quantity and quality has been recognized. Task 4 addresses this need by providing the technical support necessary to develop a hydrologic assessment for RMA.

Under this task a one year ground water and surface water surveillance program will be performed at RMA to achieve the following objectives:

- o Satisfy compliance oriented regulatory requirements under Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Resource Conservation and Recovery Act (RCRA) and the intent of the Cease and Desist Order;

- o Confirm the existence and chemical nature of known contamination and monitor any changes in the lateral and vertical extent of contaminant migration; and
- o Develop a core data base for use in upcoming litigation and Remedial Investigation/Feasibility Study analyses for RMA.

All studies under this task will be performed in accordance with the requirements and technical specifications discussed in Section C-3 and Appendices A (U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) Quality Assurance Program, 1982) and B (USATHAMA Geotechnical Requirement, 1983) of Contract DAAK11-84-D-0016, except where modified as required for technical/litigation standardization. Standardized methods, protocols, and criteria will be consistent with those proposed in Tasks 1 and 2, and as standardized during subsequent meetings between the government and contractors. Services will consist of collection, analysis, reduction and compilation of environmental data for both surface and ground water. Data will be collected during a 12-month period and will include stream flow, ground water level, and water quality evaluations. Acquired data will be utilized as input into the litigation effort.

1.2 GEOLOGY

The topography at RMA consists of rolling hills, expansive areas of plains, and small enclosed basins. The maximum local topographic relief is approximately 220 feet (ft). The elevation above mean sea level (MSL) ranges from 5,340 ft at the southern boundary to 5,120 ft at the northern extent. The topographic surface slopes gently northwest towards the South Platte River at approximately 0.35 degrees (Figure 1.2-1).

RMA is located within the geologic province of the Denver Basin, a structural depression resulting from tectonic adjustments which occurred intermittently throughout time. The basin exhibits an elongate, north-south trending surface expression 300 mi long and 200 mi wide in north-central Colorado, Wyoming, and Nebraska. The basin is bound by the mountains of the Front and Laramie Ranges on the west, the Hartville Uplift and Chadron Arch on the north, and the Las Animas Arch and

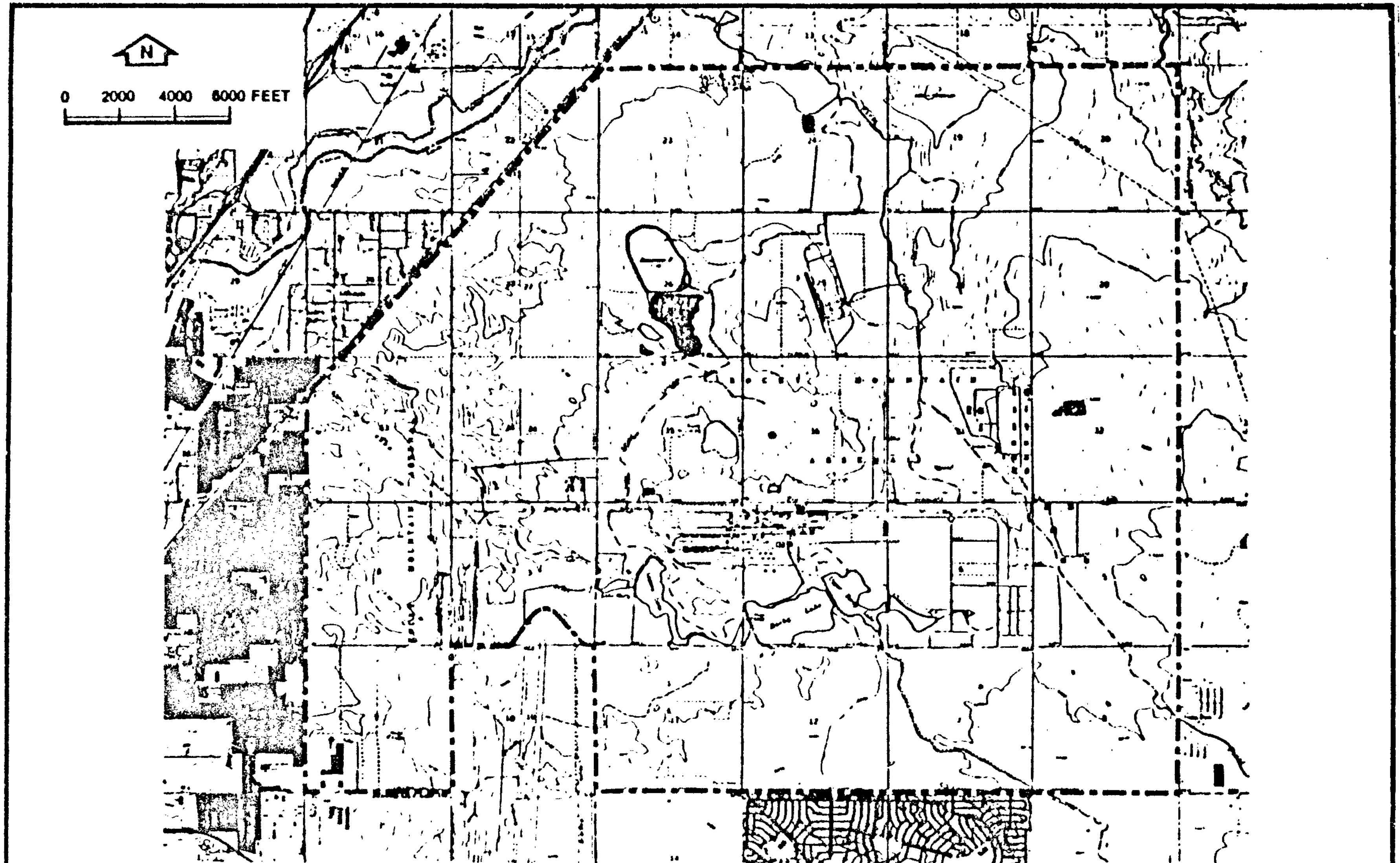


Figura 1.2-1
TOPOGRAPHIC MAP OF RMA
(CONTOUR INTERVAL - 10 FEET)

SOURCE: USGS, 1979

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

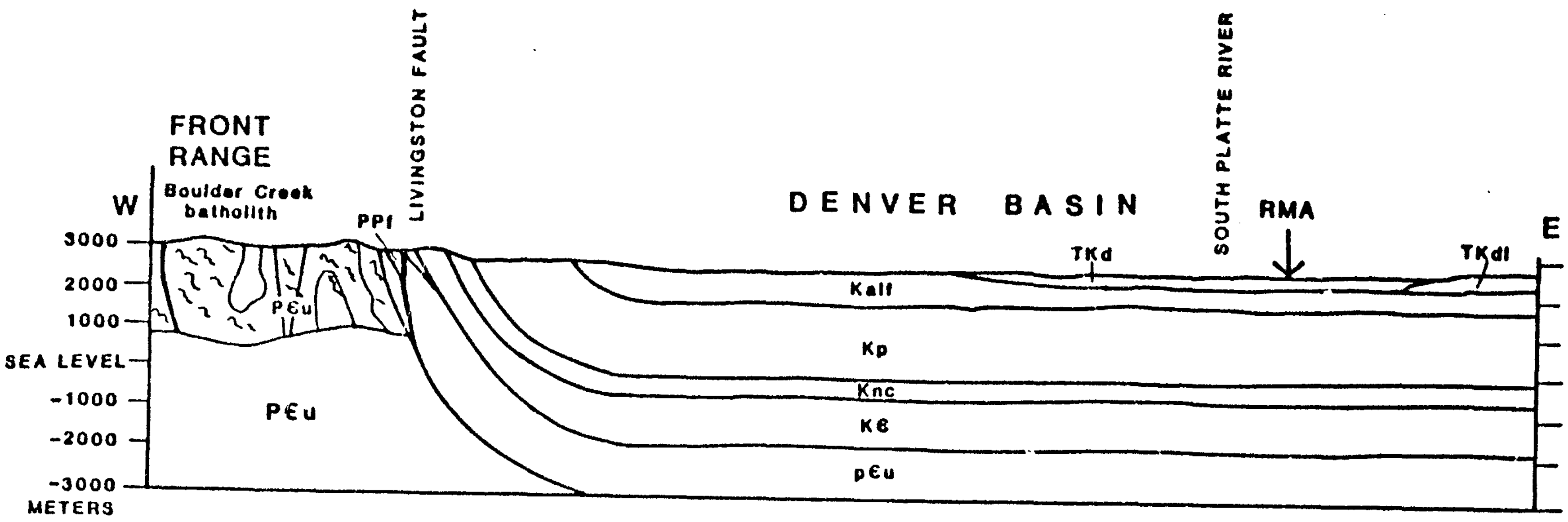
Apisuapa Uplift on the south. Sedimentary strata composed of conglomerate, sandstone, shale, and limestone lithologies rest on the Precambrian basement and fill the synclical structure (Figure 1.2-2). Strata range in age from Cambrian to Quarternary.

RMA lies on a bedrock surface formed by the late Cretaceous-early Tertiary Denver Formation. Quarternary alluvial and eolian deposits (locally referred to as alluvium) mantle the surface and obscure the Denver over most of RMA (Figure 1.2-3). Regional dip is to the southeast.

The basin acquired its present configuration during the late Cretaceous-Tertiary Laramide Orogeny. Normal faulting, regional uplift, mountain glaciation, and development of the present drainage system characterize the late Tertiary to recent history of RMA. The episodes caused extensive erosion which removed great thicknesses (up to 1,400 ft) of the Denver Formation and carved the paleochannels which underlie the surficial deposits on RMA (Costa, 1982).

Sediments present at the land surface consist of unconsolidated alluvial and eolian deposits of the Quaternary age. The material is composed primarily of alluvial fill, dune sand, and glacial outwash which contains cobbles, boulders, and beds of volcanic ash as well as sands, gravels, silts, and clays. Combined thickness of the surficial materials ranges from 30 to 130 ft. The thicker deposits represent filling of the paleochannels cut in the surface of the Denver Formation. Lithologic logs in the intrachannel areas indicate anomalously thick sequences of overburden drilled before penetrating the Denver. Colors range from yellow-brown to pale orange and are a product of oxidation. Locally, deposits may be consolidated where calcium carbonate has cemented sands and gravels to form conglomerates.

The Denver Formation underlying RMA consists of 250 to 400 ft of olive, bluish gray, green-gray, and brown clay-shale and siltstone interbedded with poorly sorted, weakly lithified tan to brown, fine to medium grained sandstone. Lignite beds and carbonaceous shales are common, as are



TKdl DAWSON ARKOSE (TERTIARY - UPPER CRETACEOUS)

TKd DENVER FORMATION (TERTIARY - UPPER CRETACEOUS)

Kalf ARAPAHOE FORMATION, LARAMIE FORMATION, FOX HILLS SANDSTONE (UPPERCRETACEOUS)

Kp PIERRE SHALE (UPPER CRETACEOUS)

Knc NIOBRARA FORMATION, CARLILE SHALE, GREENHORN LIMESTONE, GRANEROS SHALE, (UPPER CRETACEOUS)

K€ DAKOTA SANDSTONE(UPPER CRETACEOUS) AND UNDERLYING MESOZOIC PALEOZOIC ROCKS

PPf FOUNTAIN FORMATION (PERMIAN - PENNSYLAVANIAN)

P€u PRECAMBRIAN UNDIFFERENTIATED

Figure 1.2-2
GENERALIZED GEOLOGIC CROSS SECTION THROUGH THE AREA OF RMA (NOT TO SCALE)
SOURCE: ESE, 1985

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U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

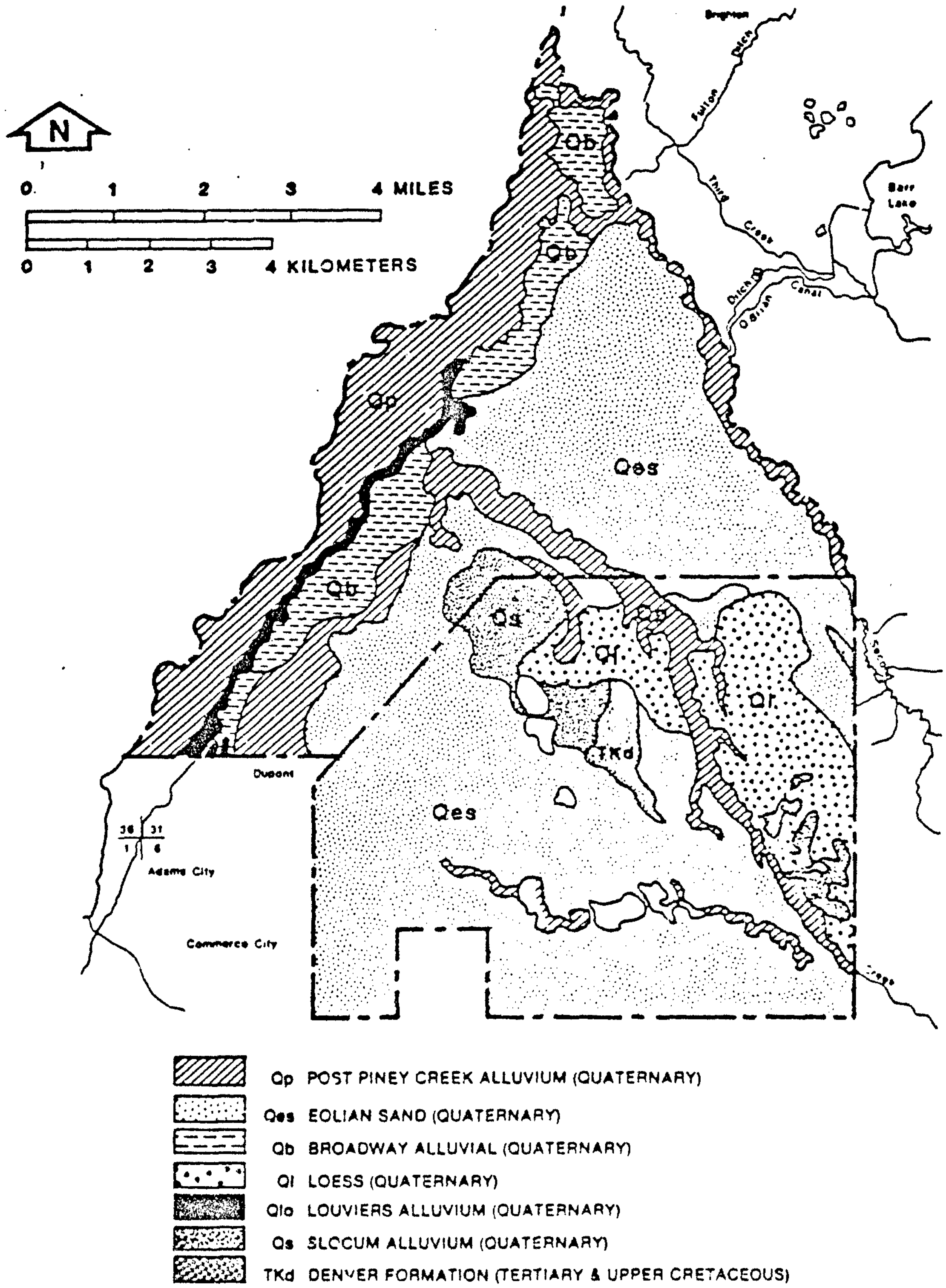

Figure 1.2-3
GEOLOGIC MAP OF RMA AREA

SOURCE: USGS. 1981.

Prepared for:
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For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

volcanic fragments and tuffaceous materials. The clay-shale is largely bentonitic. Sandstones are mainly lenticular and are sinuous in nature. These lenses are distributed within thick clay-shale sequences and are poorly defined where the sandstones grade into the encompassing clay and shale. The sandstones are discontinuous to semi-continuous.

1.3 GROUND WATER HYDROLOGY

Ground water resources in the area are part of the Denver ground water basin (Figure 1.3-1). The basin underlies the area extending from Greeley, Colorado in the north to Colorado Springs, Colorado in the south and from the Front Range Uplift on the west to near Limon, Colorado in the east. Formations ranging in age from Pennsylvanian to Tertiary contain water bearing units (Figure 1.3-2). The four major bedrock aquifers are the Laramie-Fox Hills, the Arapahoe, the Denver, and the Dawson. Surficial deposits as well as the crystalline rocks of the Front Range locally yield sufficient quantities of water to be considered aquifers.

The geologic formations containing the four major bedrock aquifers are the Fox Hills Sandstone and the Laramie and Arapahoe Formations of late Cretaceous age, the Denver Formation of late Cretaceous and early Tertiary age, and the Dawson Arkose of Tertiary age (Romero, 1976). These formations occur in a sequence of layers as shown by the generalized geologic sections drawn from west to east and from south to north through the basin (Figure 1.3-3). The northern, eastern and southern parts of the basin form a shallow bowl, the sides of which dip gently toward the west-central part of the basin. Along the western edge of the basin, sedimentary formations are upturned against the Precambrian crystalline rocks of the Front Range and dip steeply to the east as a result of faulting and the gradual upward movement of the Rocky Mountains. The Pierre Shale of late Cretaceous age underlies the Fox Hills Sandstone and is considered to be the base of the major bedrock-aquifer system due to its great thickness and its minimal permeability (Robson and Romero, 1981).

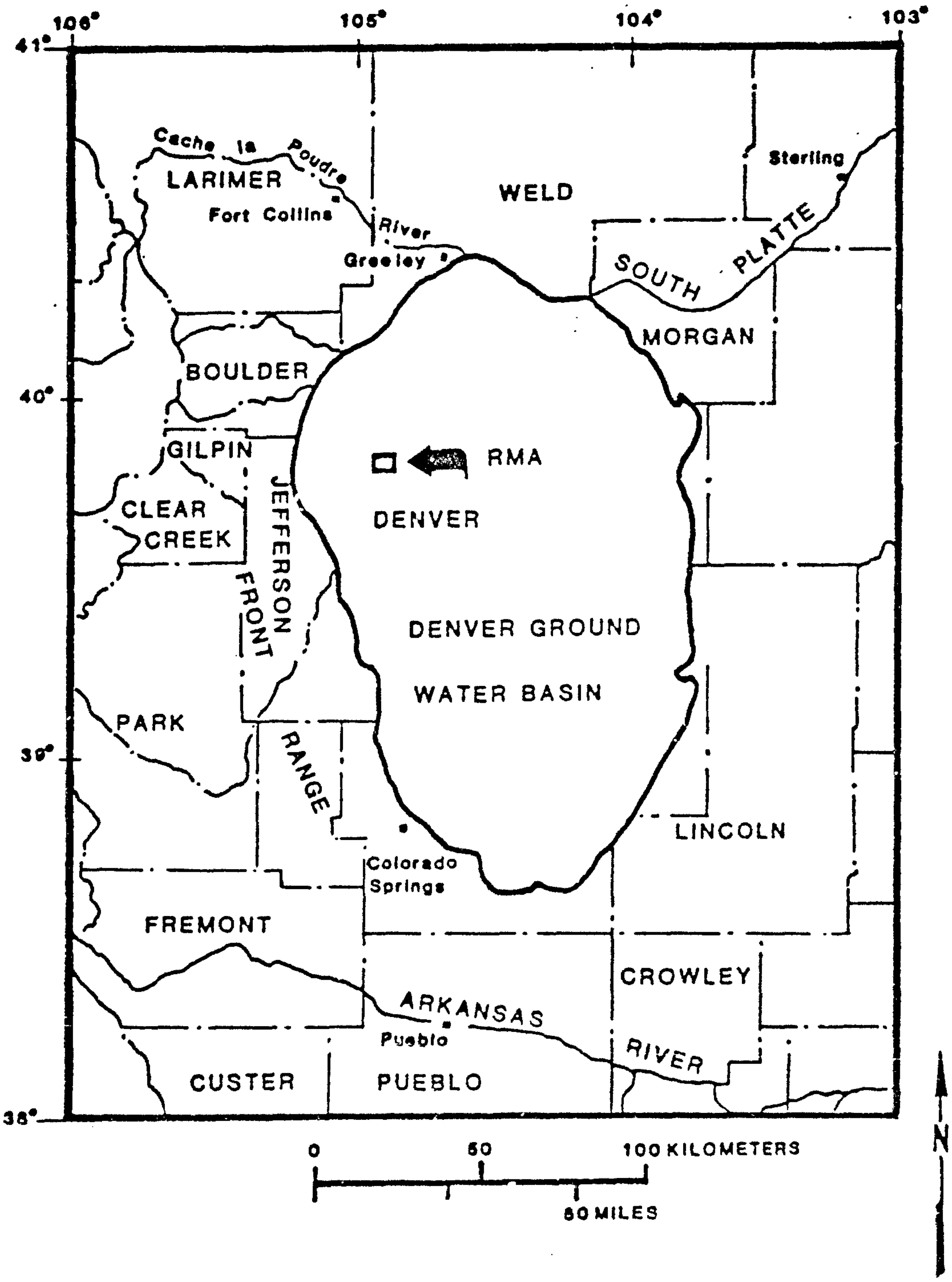

Figure 1.3-1
DENVER GROUND WATER BASIN

SOURCE: ROBSON, 1981

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Era	System or Period	Series	Geologic Unit	
Cenozoic	Quaternary	Recent and Pleistocene	**Quaternary surficial deposits**	**Stream channel, flood-plain and terrace deposits; eolian sand, etc.**
	Tertiary	Oligocene	**Castle Rock Conglomerate**	
			Tertiary intrusive and extrusive rocks	
Cenozoic and Mesozoic	Teriary and Cretaceous	Paleocene —?— Upper Cretaceous	Dawson Group	**Dawson Arkose**
				Denver Formation
				Arapahoe Formation
Mesozoic	Cretaceous		Laramie Formation	**Upper part**
				B sandstone
				A sandstone
			Fox Hills Sandstone	**Milliken Sandstone**
				lower part
			Pierre Formation	
			Niobrara Formation	Smoky Hill Shale
				Fort Hayes Limestone
			Brenton Formation	Carlile Shale
				Greenhorn Limestone
				Graneros Shale
		Lower Cretaceous	Dakota Group	**South Platte Formation**
				Lytle Formation
	Jurrassic	Upper Jurassic	Morrison Formation	
			Ralston Creek Formation	
Paleozoic	Triassic and Permian		Lykins Formation	Strain Shale
				Glennon Limestone
				Bergan Shale
				Falcon Limestone
				Harriman Shale
	Permain		**Lyons Sandstone**	
			Fountain Formation	
	Pennsylvanian		Glen Eyrie Formation	
	Mississipian		Madison Limestone	
			Williams Canyon Limestone	
	Ordovician and Cambrian		Manitou Dolomite	
	Cambrian		Sawatch Sandstone	
Precambrian			crystalline rocks	

Principal Aquifers In Boldface Type

Figure 1.3-2
GENERALIZED COMPOSITE SECTION OF THE GEOLOGIC UNITS OF THE DENVER BASIN
SOURCE: ROMERO, 1976

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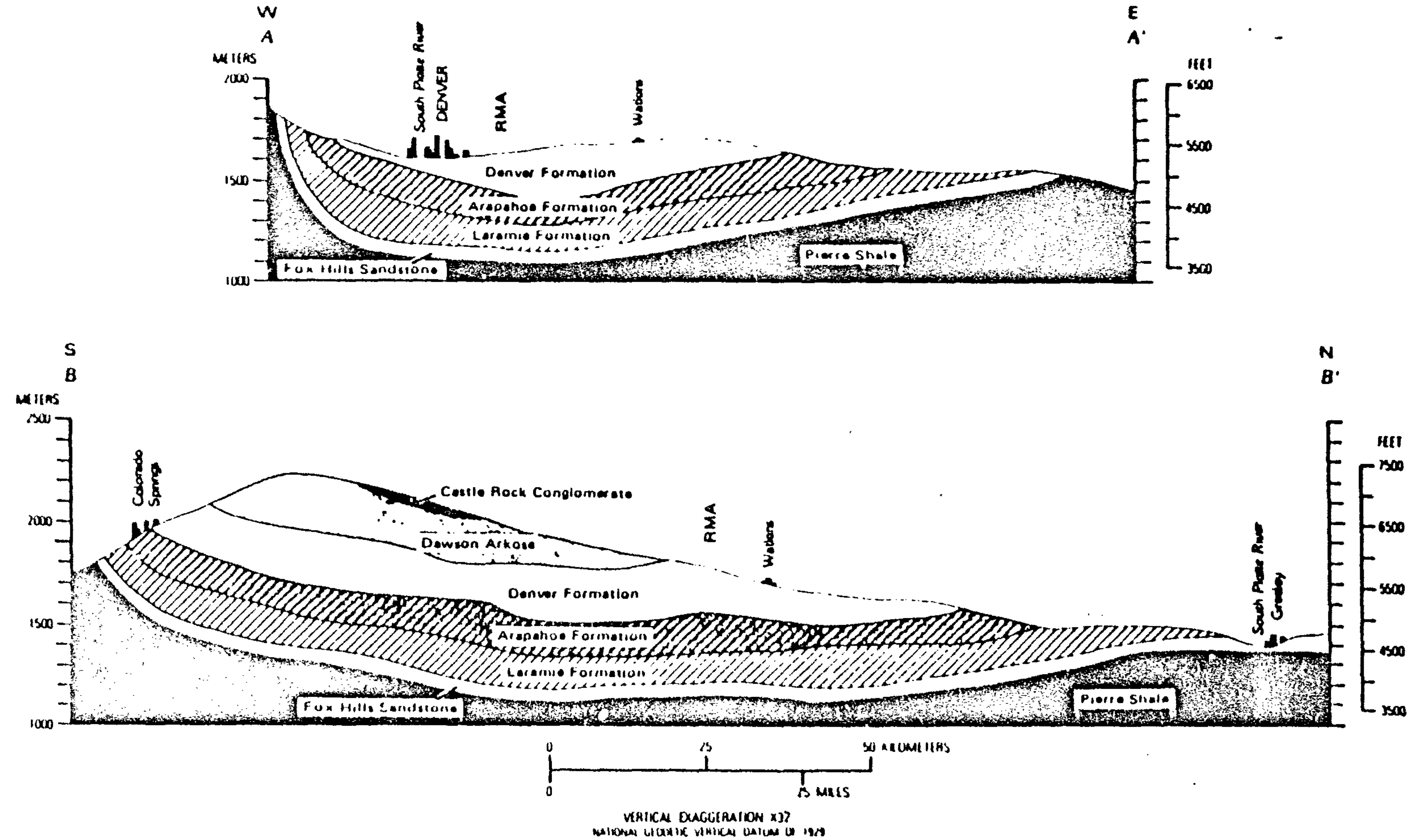

Figure 1.3-3
UPPER STRATIGRAPHIC SECTIONS OF DENVER BASIN

SOURCE: ROBSON, 1981

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The strata of primary concern at RMA are the Arapahoe Formation, the Denver Formation, and the unconsolidated Quaternary alluvial and eolian surficial deposits. Aquifers within these units compose the ground water regime in the area.

In the vicinity of RMA, a shale-claystone layer, ranging in thickness from 75 to 200 ft, separates the Denver Formation from the underlying Arapahoe Formation (Romero, 1976). Therefore, the ground water flow system of immediate concern at RMA consists primarily of the Denver aquifer and overlying unconsolidated deposits. The contact between the surficial deposits and the underlying Denver Formation is often marked by a zone of weathered bedrock. Where present, the zone is thin and should not be confused with the thicker Denver Sands that can be in contact with the alluvium. The zone is considered to be part of the alluvial aquifer system.

Unconsolidated surficial sediments make up the alluvial aquifer at RMA. The ground water is generally under atmospheric pressure, creating water table conditions. Locally, clay lenses within the aquifer produce perched or confined conditions.

The entire sequence of surficial materials should be considered capable of bearing water. Overall permeability of the deposit is enhanced by the coarse nature of the materials, especially in the paleochannels where the bulk of the basal fill consists of gravels, cobbles, and boulders. Paleochannels are likely to serve as the major alluvial ground water transport pathways (Figure 1.3-4).

As determined from pumping tests the hydraulic conductivity (permeability) of the alluvial aquifer ranges from approximately 1.0 to 1.0×10^{-3} centimeters per second (cm/sec) (May, 1982), with the higher values associated with buried channels. The transmissivity ranges from 1,500 to 250,000 gallons per day per foot (gpd/ft) while the storage coefficient ranges from less than 10^{-5} to more than 0.4 (RMA-CCPMT, 1983).

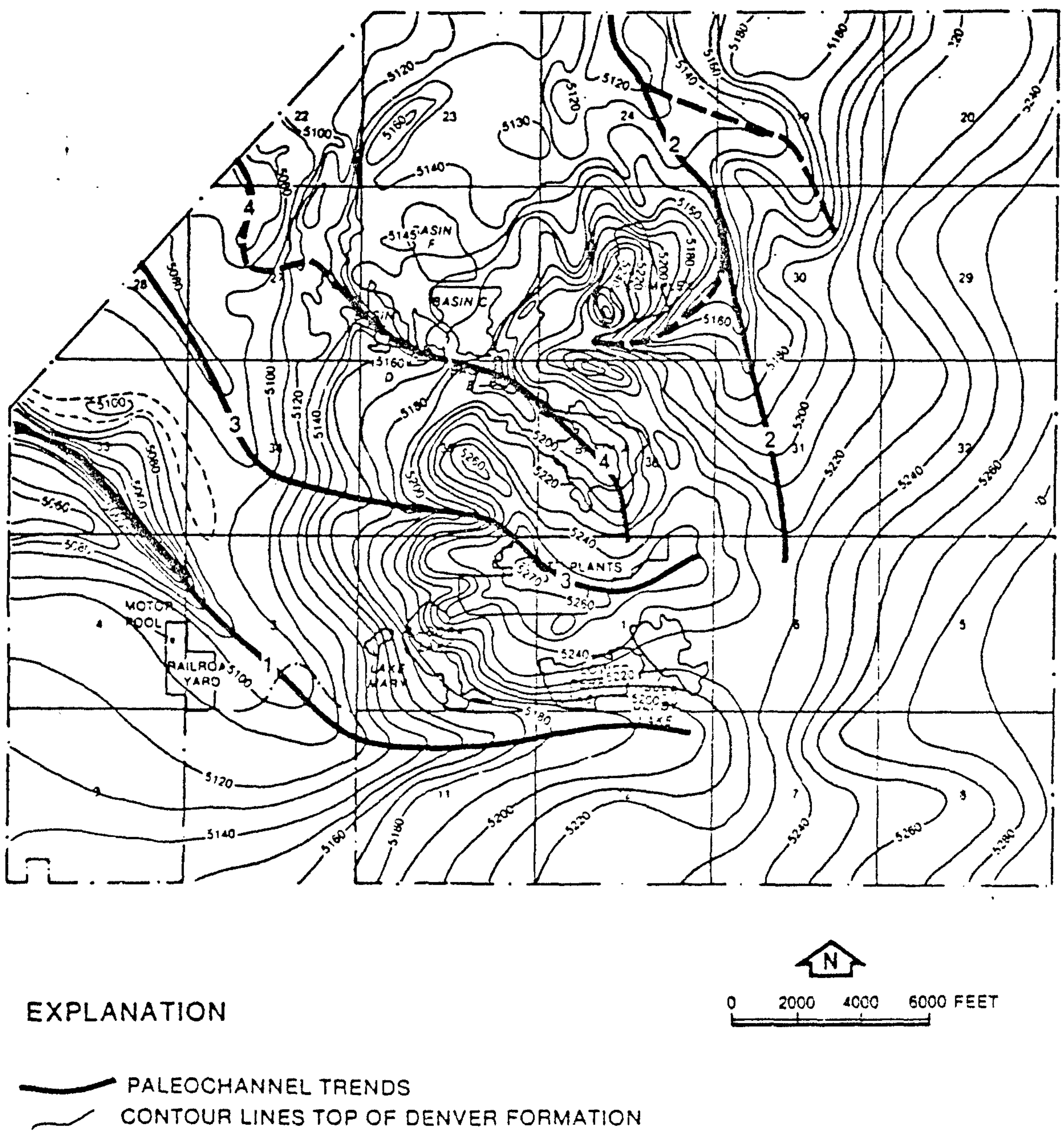

Figure 1.3-4
CONTOUR MAP - TOP OF DENVER FORMATION

SOURCE: RMA-CCPMT, 1983

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

07/07/86

The Denver aquifer, also referred to as the lower aquifer, bedrock aquifer or Denver Sands, is composed primarily of lenses of weakly cemented sandstone or compact fine to medium grained sandstones. These lenticular sandstones grade laterally and vertically into relatively impermeable silts and clay-shales. Primary ground water transport takes place in the lenses and paleochannels, where flow occurs in the void spaces between the coarser materials.

As determined from slug tests and laboratory tests, the hydraulic conductivity of the Denver Sands is approximately 10^{-3} to 10^{-4} cm/sec compared to 10^{-7} cm/sec for the clay-shales (May, 1982). The transmissivity of the sands ranges from 10 to $1x10^{-5}$ gpd/ft and storage coefficients are highly variable ranging from 10^{-1} to 10^{-8}.

The ground water flow paths of the two primary aquifers at RMA are complicated by the following factors:

- Contrasts in permeability between the buried channels, adjacent alluvium, and weathered bedrock that make up the alluvial aquifer;
- Contrasts in permeability between the Denver Sands, adjacent clay shales and overlying alluvial materials;
- The complex relationships between the two aquifers; and
- The geometry of the recharge and discharge areas.

Flow within the alluvial aquifer generally occurs in a north to northwesterly direction, perpendicular to the water table gradient (Figure 1.3-5). Variations to this general pattern occur as a result of the strong control on permeability exerted by the buried channels within the alluvium. Variations are also a result of recharge from spills and leaking water lines in the South Plants Area and infiltration of surface water in Basin A, which have resulted in a large ground water mound in this area. Other sources of recharge to the alluvium include infiltration of precipitation, regional flow that enters the alluvial aquifer to the south of RMA, and possible recharge from upward flow from the underlying Denver Sands. Ground water in the alluvial aquifer beneath RMA flows offsite beneath the north and northwest boundaries and eventually

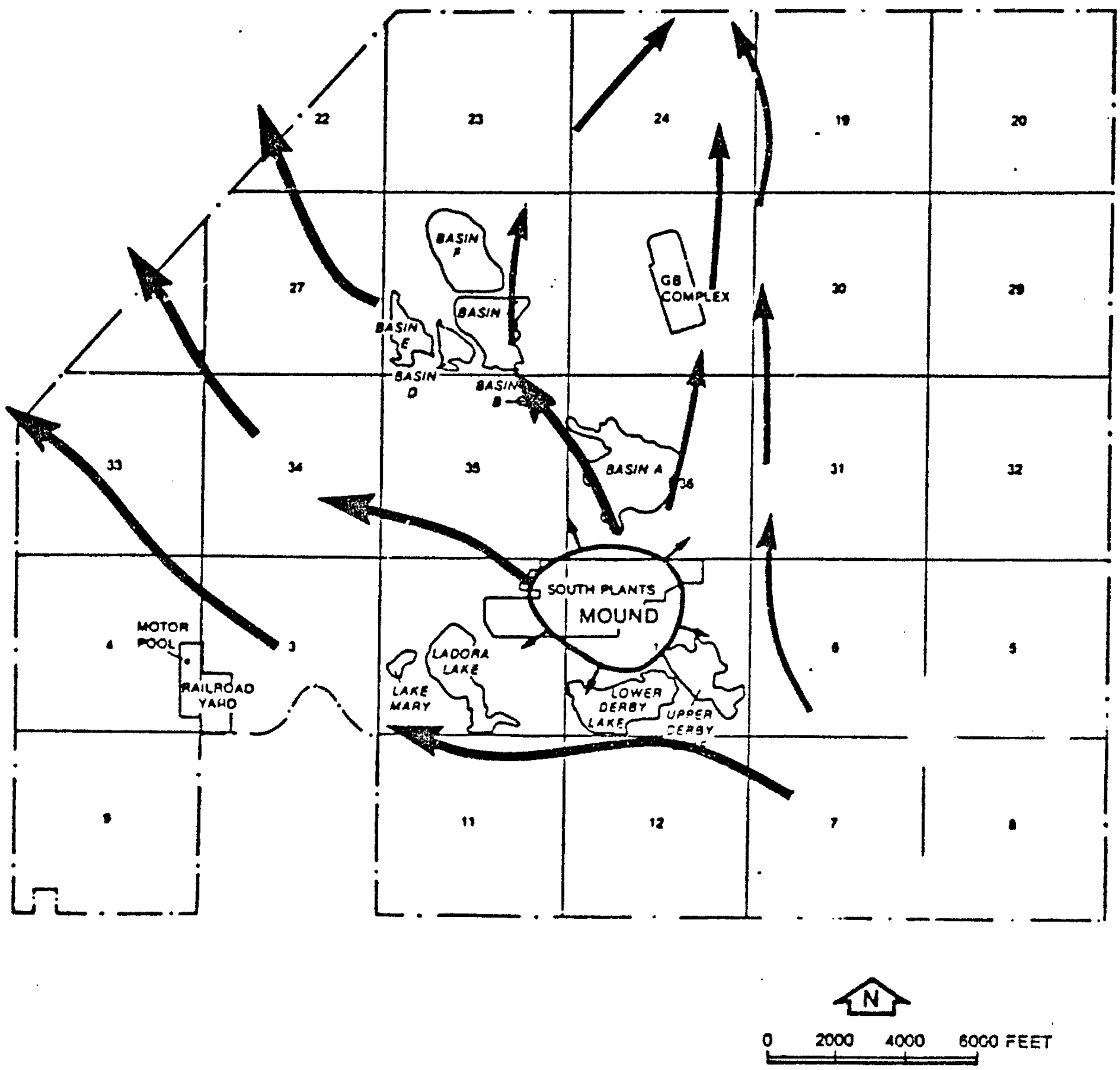

Figure 1.3-5
PRIMARY GROUND WATER FLOW COMPONENTS

SOURCE: MAY, 1982

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

discharges to the South Platte River or is removed from the aquifer by high capacity municipal and agricultural supply wells located downgradient of RMA.

Ground water flow within the Denver Sands also occurs in a generally north to northwesterly direction. Due to the confining effect of the clay shales, and the fact that the Denver aquifer is recharged by the overlying Dawson Arkose south of RMA, artesian conditions exist in much of the aquifer. Recharge to the Denver occurs as downward flow from the overlying Dawson Aquifer to the south of RMA, infiltration of precipitation on the outcrop area along the margins of the Denver basin, and locally as downward flow from the overlying alluvial aquifer (Figure 1.3-6). Discharge from the Denver aquifer occurs primarily from flow into the underlying Arapahoe aquifer, recharge to the overlying alluvial aquifer, and discharges associated with domestic and irrigation wells.

The ground water regime in the area is relatively complex due to the unique hydrologic, stratigraphic, and topographic relationships between the Denver Formation and the overlying surficial deposits. The alluvial and Denver aquifers are partially isolated from each other by semi-permeable confining layers which restrict flow between the more permeable strata. Flow between the more permeable strata occurs where confining beds are absent, creating interconnections between aquifers (Figure 1.3-7).

1.4 SURFACE WATER HYDROLOGY

The surface water hydrology (Figure 1.4-1) at RMA is dominated by two major drainage basins: Irondale Gulch and First Creek. Portions of larger drainage basins or smaller, less significant basins account for the remaining drainage on RMA. These are Sand Creek Drainage, Sand Creek Lateral Drainage, Northwest Drainage, Basin F, Basin A, and Second Creek Basin.

First Creek occupies a well defined channel that crosses the east and north boundaries of RMA. Flow within First Creek is continuous during

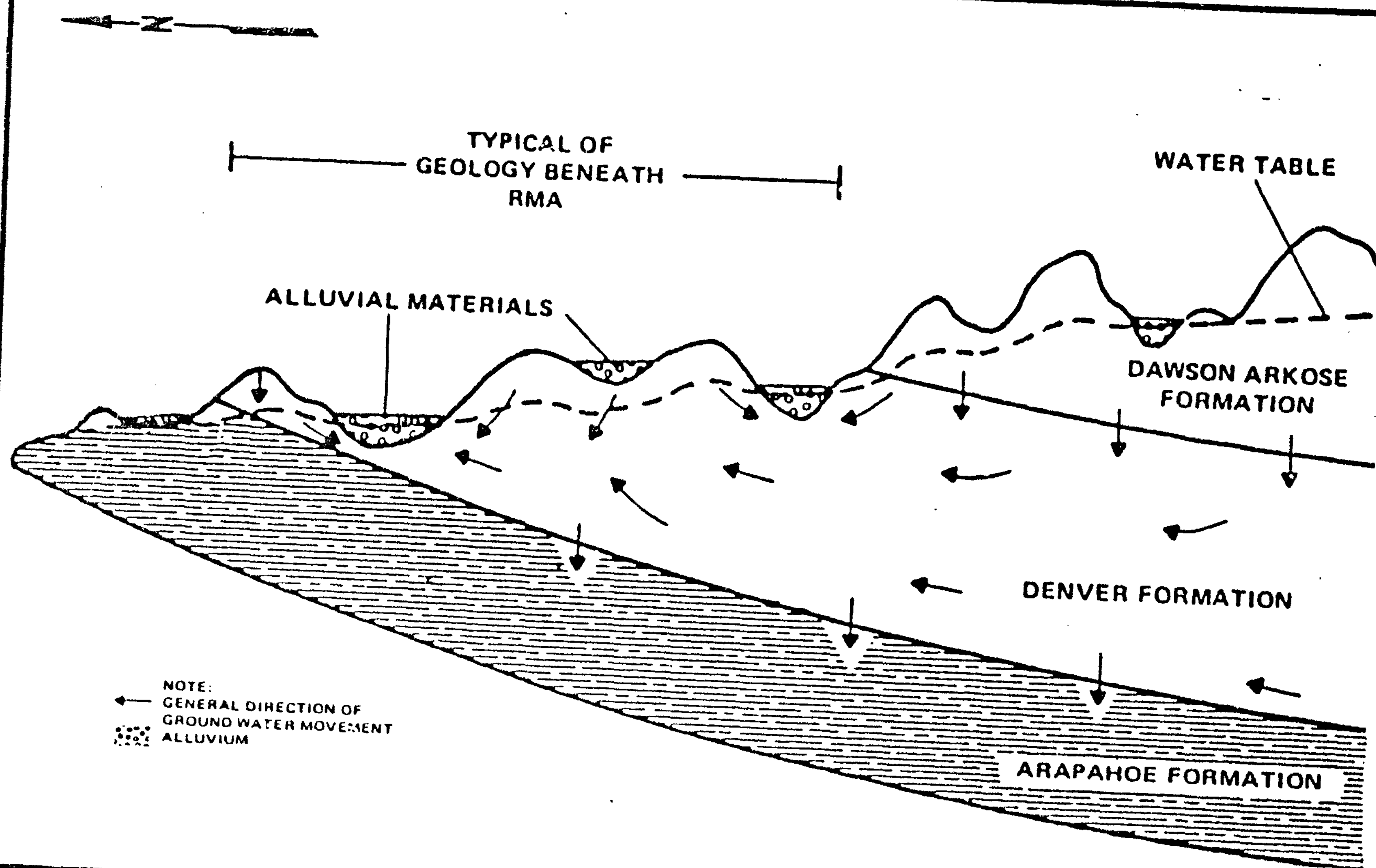

Figure 1.3-6
REGIONAL HYDROGEOLOGIC FLOW
SECTION IN THE VICINITY OF RMA

SOURCE: RMA - CCMT, 1983

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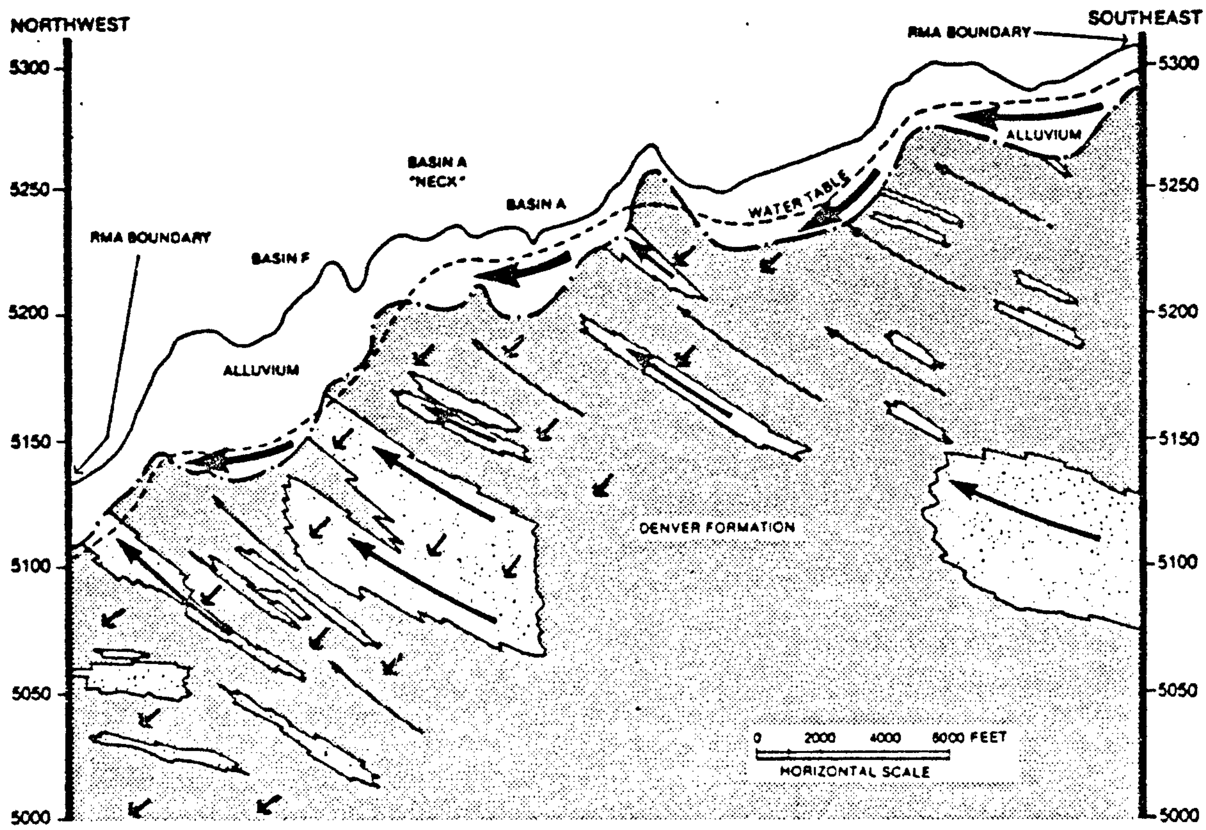

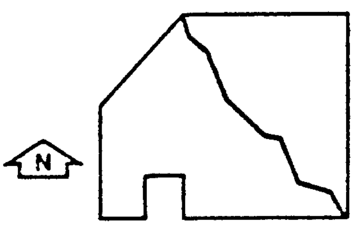

SECTION LOCATION

LITHOLOGY CODES

- ALLUVIUM
- DENVER SANDS
- DENVER SILTS & CLAYS

GEOHYDROLOGY

ARROW SIZE DENOTES MAGNITUDE OF GROUND WATER FLOW

---- WATER TABLE

—·— ALLUVIAL-DENVER CONTACT

Figure 1.3-7
HYDROGEOLOGIC SECTION ACROSS RMA

SOURCE: RMA-CCMT, 1983

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Aberdeen Proving Ground, Maryland

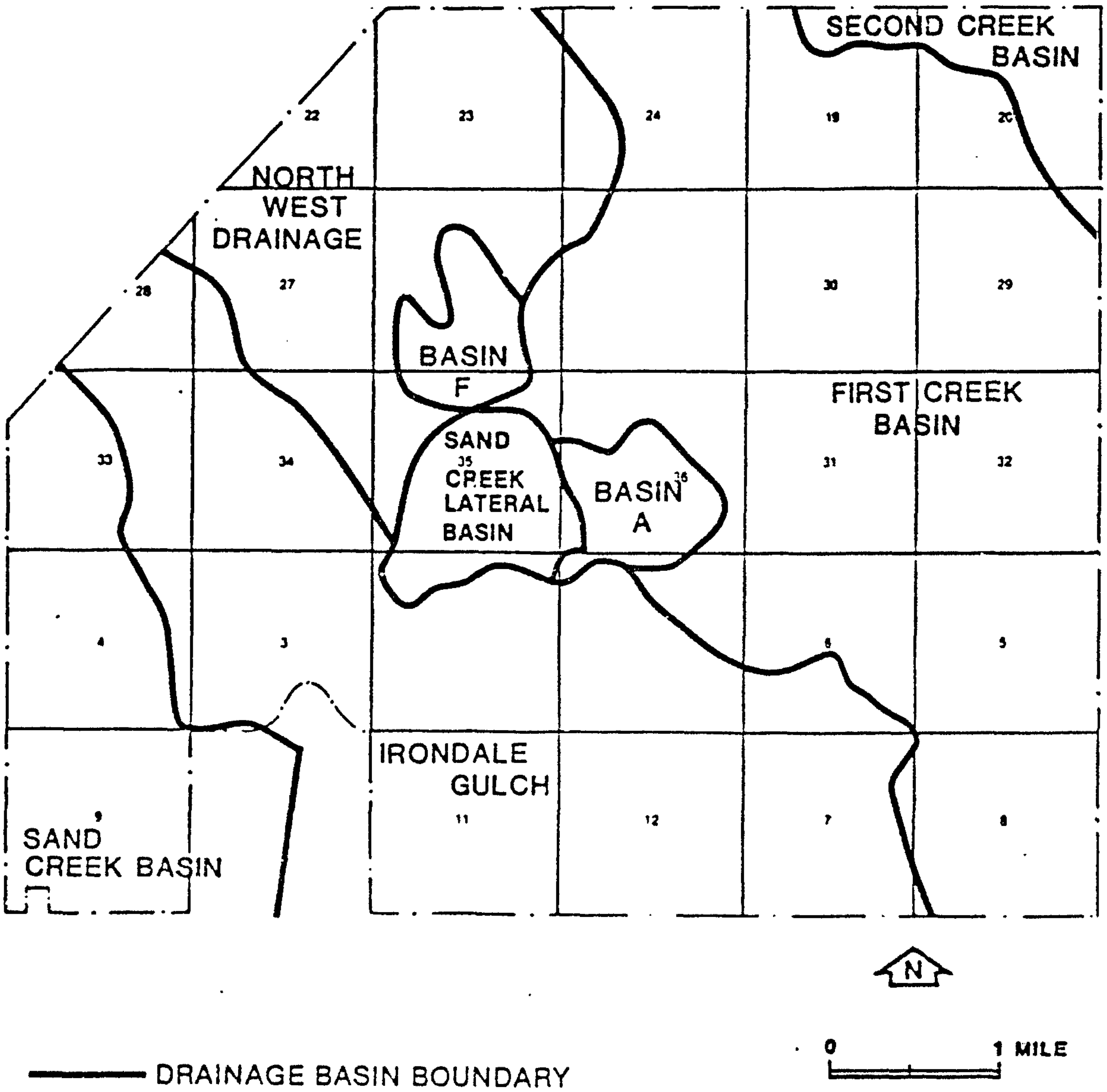

Figure 1.4-1 RMA SURFACE WATER DRAINAGE BASINS SOURCE: RCI, 1981	Prepared for: U.S. Army Program Manager's Office For Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland

the spring season and major storm events. The remaining time it is intermittent. Several tributaries contribute to flow in the creek. Flow components include surface water runoff, effluent from the Sewage Treatment Plant, and overflow drainage from the North Bog.

Irondale Gulch is characterized by poorly defined channelization, resulting in many small basins which are connected only during major flood events. The drainage area, which is much smaller than that of First Creek, has been modified by construction of subdivisions, the Lower Lakes, man-made channels, and storm drains. There are four major flow routes within this drainage basin:

- The Highline Lateral is a man-made channel which serves as an overflow for creeks in southeastern Denver. Flows are occasional and controlled by man-made structures. Water in the Lateral ultimately reaches Lower Derby Lake or Upper Derby Lake;
- The Uvalda Interceptor collects storm runoff from the residential area south of RMA and transports it to Lower Derby Lake or Upper Derby Lake. This is a well defined unlined channel which has been breached during major flood events;
- The flows in the Havana Interceptor consist of storm and nuisance flows from Stapleton, a large industrial complex, and portions of the Montbello residential area. The flows empty into a large surface impoundment, known as Havana Pond, that acts as a source of recharge to the ground water. Water from the pond can also be released through an unlined ditch that runs east to the Sand Creek Lateral; and
- The final major flow route within the Irondale Gulch drainage is the Lower Lakes. The Lower Lakes consist of four man-made lakes and one pond. Upper Derby Lake serves as an overflow in case of flood. Lower Derby Lake, which receives the local storm runoff, is in direct contact with the water table. Lake Ladora serves as a cooling water source for the RMA power station and is also in direct contact with the water table. The Derby and Ladora Lakes are both recharge and discharge areas. During periods of high flow (March through August),

ground water is replenished through these lakes. During periods of low surface flows (September through February), ground water is released to surface water through the lakes. Lake Mary, located west of Ladora Lake, is not in contact with the water table and therefore is primarily a recharge area. The Rod and Gun Club Pond was created during a major flood. This pond is usually dry except during major flood events when it receives overflow from the Uvalda Interceptor and Lower Derby Lake.

In addition to the First Creek and Irondale Gulch drainage basins, many minor flow paths exist on RMA (Figure 1.4-2). Sand Creek Drainage occupies RMA's southwest corner and is adjacent to Irondale Gulch. The drainage exhibits a lack of any major channelization and any flow would be local during periods of extreme rainfall; flowing overland short distances to one of the many natural depressions found in the basin.

The Northwest Drainage lies in the northwest corner of RMA. It is bound by Irondale Gulch on the southwest, Sand Creek Lateral Drainage and Basin F Drainage on the west and north, and First Creek Basin on the east. Like Sand Creek Drainage, Northwest Drainage is virtually void of major channelized flow and has a large number of natural depressions. Surface water flows to the Northwest, like Sand Creek Drainage, would be localized and would support overland flows only after extreme rainfall events. These flows would be to the north and west boundaries of RMA.

The south portion of the Basin A drainage basin collects a large portion of the South Plants Area. Runoff from the South Plants area may be transported to Basin A via the contaminated waste lines or through culverts under December 7th Avenue. Once drainage from South Plants crosses December 7th Avenue, it enters the old Basin A contaminated waste seepage/evaporation pond. In the past when this area was used for disposal of contaminated wastes, the natural depression was modified through the use of embankments to provide greater storage. Because this basin no longer receives contributions from waste streams, it is felt that the storage capacity of Basin A would contain virtually all incident

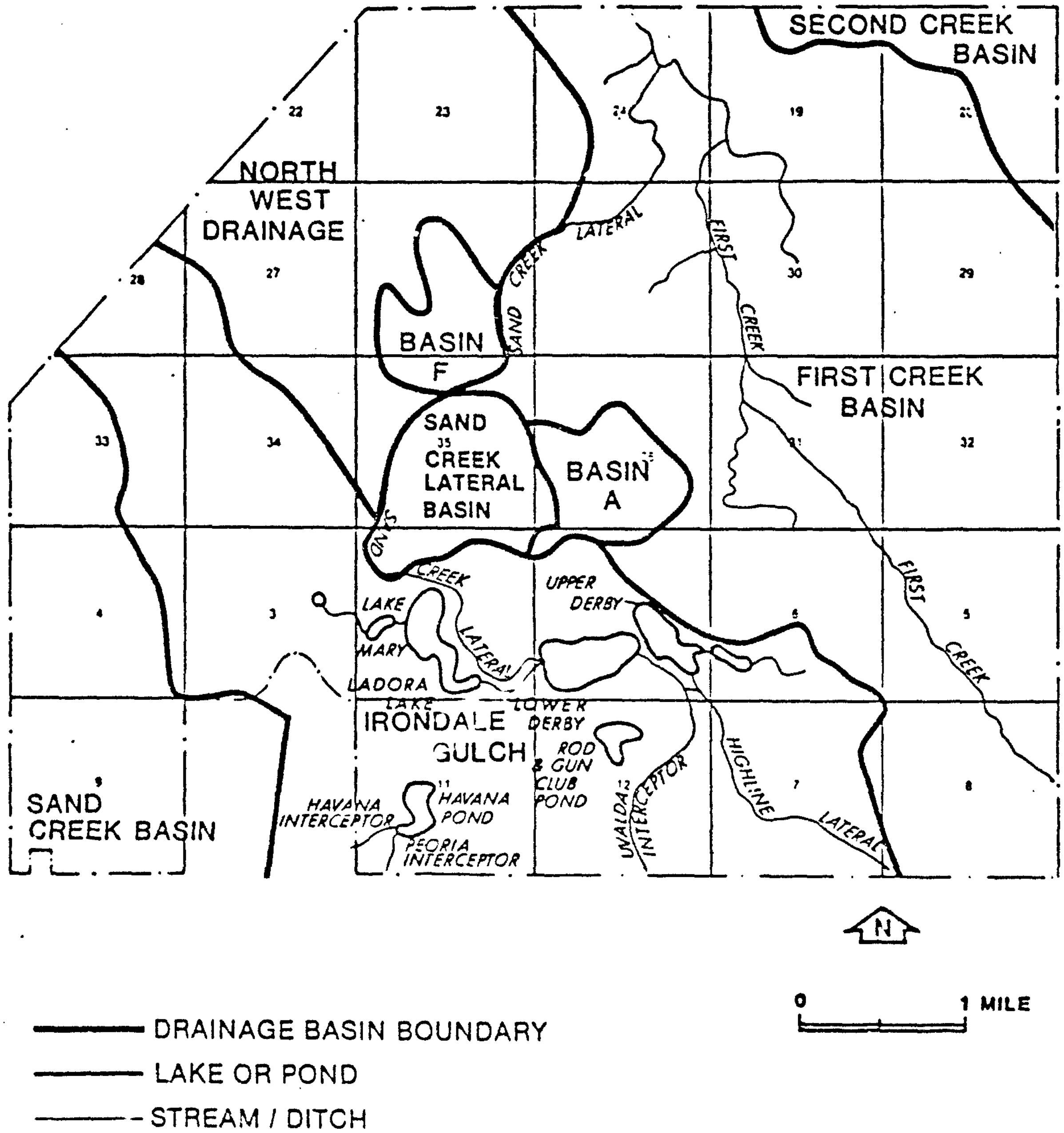

Figure 1.4-2
RMA SURFACE WATER FEATURES

SOURCE: RCI, 1981

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local precipitation. However, surface water overflows may occur during peak runoff events.

Sand Creek Lateral Drainage is also located near the center of RMA, lying just to the west of the Basin A Drainage. Sand Creek Lateral Drainage is slightly larger than the Basin A Drainage. Sand Creek Lateral Drainage has one major channel, the Sand Creek Lateral. This channel forms the north and west boundaries of the drainage and intercepts the flows from the drainage area. Flow is to the northwest, and occurs only after large precipitation events. Near the north end of the drainage, Sand Creek Lateral is blocked immediately downstream of a diversion structure which irrigates the southern portion of the Basin F Drainage. A secondary channel in the Sand Creek Lateral Drainage originates near the lime settling ponds in Basin A. This channel flows under Sand Creek Lateral at the point where the two cross and then it flows into the Northwest Drainage. The Sand Creek Lateral Drainage contains a dry reservoir. In the past the reservoir was used as a caustic waste basin, filled by means of a pipeline from the South Plants Area. This basin has no formal outlet and is currently dry.

The Basin F Drainage is just to the north of the Sand Creek Lateral Drainage, bounded on the east by the First Creek Basin and on the west by Northwest Drainage. The area of the Basin F Drainage includes Basins C, D, E, and F. Currently, it is assumed that all local flows generated in the Basin F Drainage as a result of precipitation events will flow to the nearest depression (i.e., Basins C, D, E, and F). The only source of flow other than direct precipitation is a channel which flows from Basin B located in the First Creek Basin. This channel flows under Sand Creek Lateral northwest to Basin C. Inflows to Basin B are in the form of two overflow channels originating from Basin A. As mentioned earlier, it is doubtful that any flow will enter the Basin F drainage system via these channels.

1.5 CONTAMINANT SOURCES

The primary sources of ground water contamination at RMA are the South Plants Area, Basins A, C, D, E, and F, the chemical sewer system, and the

rail classification yard (Figure 1.5-1). These sources occur in five general vicinities and are discussed below.

1.5.1 SOUTH PLANTS AND BASIN A

Operations at the South Plants Area began in 1942 with the manufacture of chemical munitions and subsequent production of pesticides and herbicides. Chemical wastes from these operations were discharged into the lime settling ponds which at times have overflowed into Basin A, or were directly discharged to Basin A via the chemical sewer system. In addition to the controlled discharge of wastes, numerous uncontrolled discharges have occurred in this area including a major benzene spill in 1948, pesticide spills, discharges of wastes to small disposal ponds throughout the area, infiltration and exfiltration of contaminants from the sewer system, and infiltration of contaminated water from building basements and sumps. All of these processes have contributed to the overall degradation of the ground water quality at RMA and the origin of several contaminant plumes.

1.5.2 BASIN F

Basin F was constructed in 1956 in response to the need for expanded waste storage. In order to restrict contaminant migration, the 93 acre basin was constructed with an asphalt lined bottom protected with a 12 inch (in) thick layer of sand. Over time numerous processes have affected the performance of the Basin F System. These include:

- o Wave action along the shoreline;
- o Tears in the asphalt liner;
- o Cyclic exposure of the liner to liquid wastes, sunlight, and weather conditions; and
- o Incompatibility of some of the wastes and the asphalt liner.

These problems have resulted in discharges of wastes to the underlying alluvial aquifer and the generation of contaminant plumes that originate at Basin F.

1.5.3 BASINS C, D, AND E

Basin C is an unlined evaporation pond which was designed to receive discharge from the GB Plant. The basin has also held large volumes of

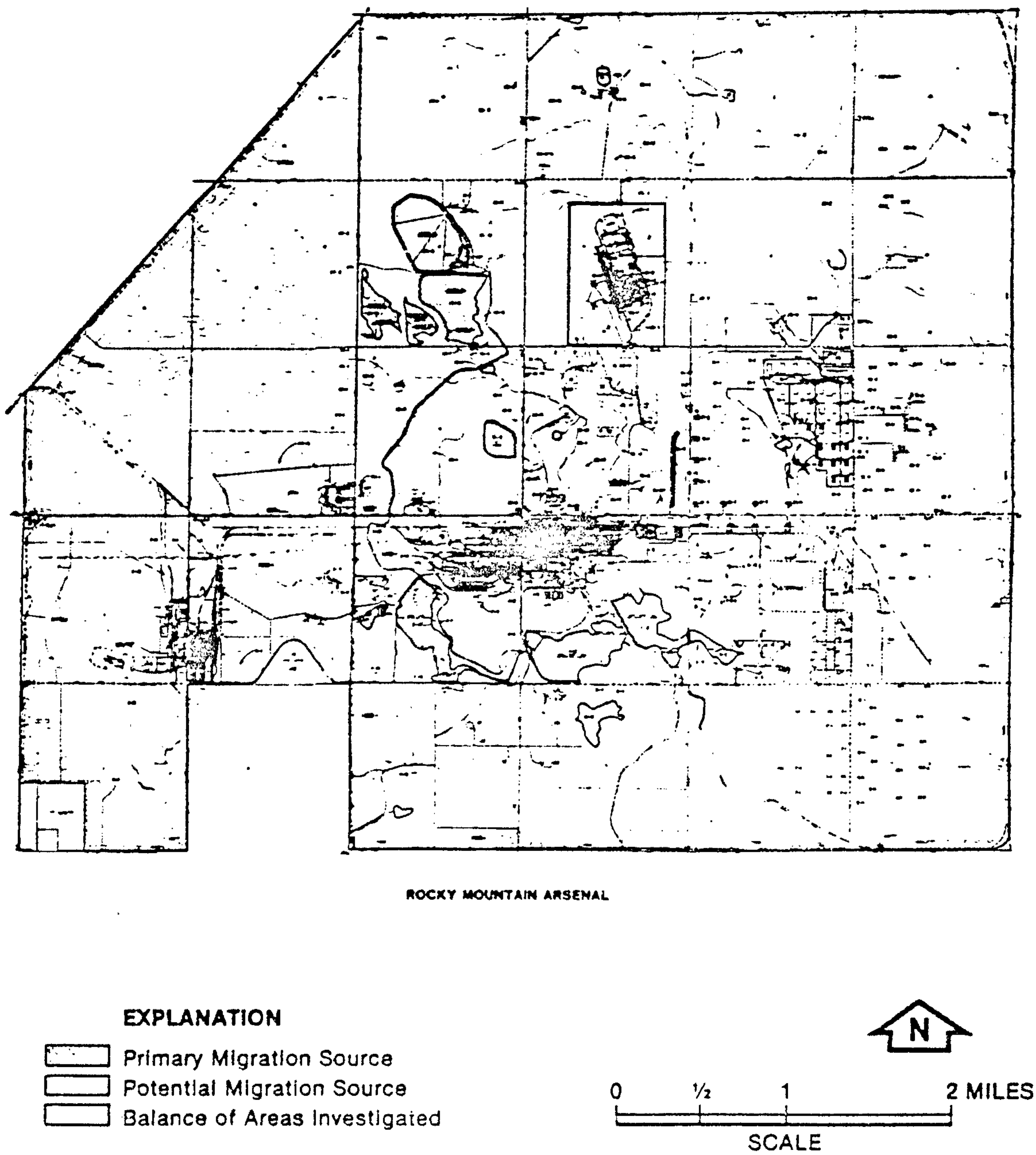

Figure 1.5-1
AREAS INVESTIGATED AS
MIGRATION SOURCES ON RMA

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fresh water from the Sand Creek lateral. In addition, approximately 100 million gallons of liquid wastes were pumped into Basin C from Basin F during repair of the Basin F liner in 1957.

Basins D and E are also unlined and were used to hold overflow from Basin A prior to construction of Basin F.

Due to upgradient contribution of contaminant plumes originating from the South Plants Area and Basin A, it has been difficult to determine the magnitude of any contaminant contribution resulting from Basins C, D, and E. All basins have contained similar chemical compounds which were derived from the South Plants and GB Plant manufacturing areas.

1.5.4 CHEMICAL SEWER SYSTEM

The chemical sewer system is considered to be a major source of ground water contamination. Several sections of the system are below the water table and numerous breaks and leaks from the lines have occurred. The primary problem areas occur in Basin A, Basin A "neck", the South Plants Area, and Basin F. The sewer system contributes to the overall ground water contamination problems in these areas.

1.5.5 RAIL CLASSIFICATION YARD

The rail classification yard has been identified as the source area of the pesticide contamination that was detected in the Community of Irondale supply wells in 1980. This contamination resulted from a major spill within the rail classification yard. Smaller spills may have occurred in this area, but are not considered significant. The major spill has resulted in the generation of a distinct ground water contaminant plume, which is currently being mitigated by the Irondale Containment System.

1.6 WATER QUALITY

1.6.1 GROUND WATER

A significant effort has been devoted to monitoring RMA ground water quality over the last 10 years. Approximately 2,000 ground water

monitoring wells exist onpost at RMA. The majority of the wells have not been sampled on a routine basis.

Ground water quality data has been compiled in the USATHAMA data base and utilized to generate contaminant contour maps for the shallow ground water system. The data used to construct these maps are primarily from alluvial wells.

Figure 1.6-1 shows a generalized configuration of ground water which exceeds water quality standards with respect to selected organic compounds. This figure shows the extent of the composite contaminant plume related to organic compounds including DIMP, dieldrin, endrin, DBCP, and DCPD. The ground water flow patterns shown in Figure 1.3-5 are confirmed by the shape of the contaminant plumes as shown in Figure 1.6-1. The general northwestern trend of ground water flow is split into northern and northwestern components by the bedrock (Denver Formation) high in the northwest portion of RMA. Therefore, ground water contaminants originating from the South Plants Area and Basin A may travel to RMA's north or northwestern boundaries while contaminants from Basin F are primarily migrating toward the RMA north boundary.

Several ground water monitoring programs have been initiated and remain in operation at RMA to accomplish a variety of objectives. These include the 360° Program, the RCRA Program, and secondary sources. In addition, a number of other monitoring programs have been conducted in the past. The regional ground water monitor programs currently in operation at RMA, specifically the 360° Program and RCRA Programs, represent regulatory compliance efforts that will be consolidated under Task 4.

1.6.1.1 <u>360° Ground Water Monitoring Program</u>

The Cease and Desist Order (1975) issued by the State of Colorado required a regional surveillance program which monitors both ground water and surface water hydrology and water quality. This monitoring program, referred to as the 360° Monitoring Program, was initiated in 1975. The objectives were to satisfy the requirements of the Cease and Desist Order and to provide a basic program for RMA surveillance.

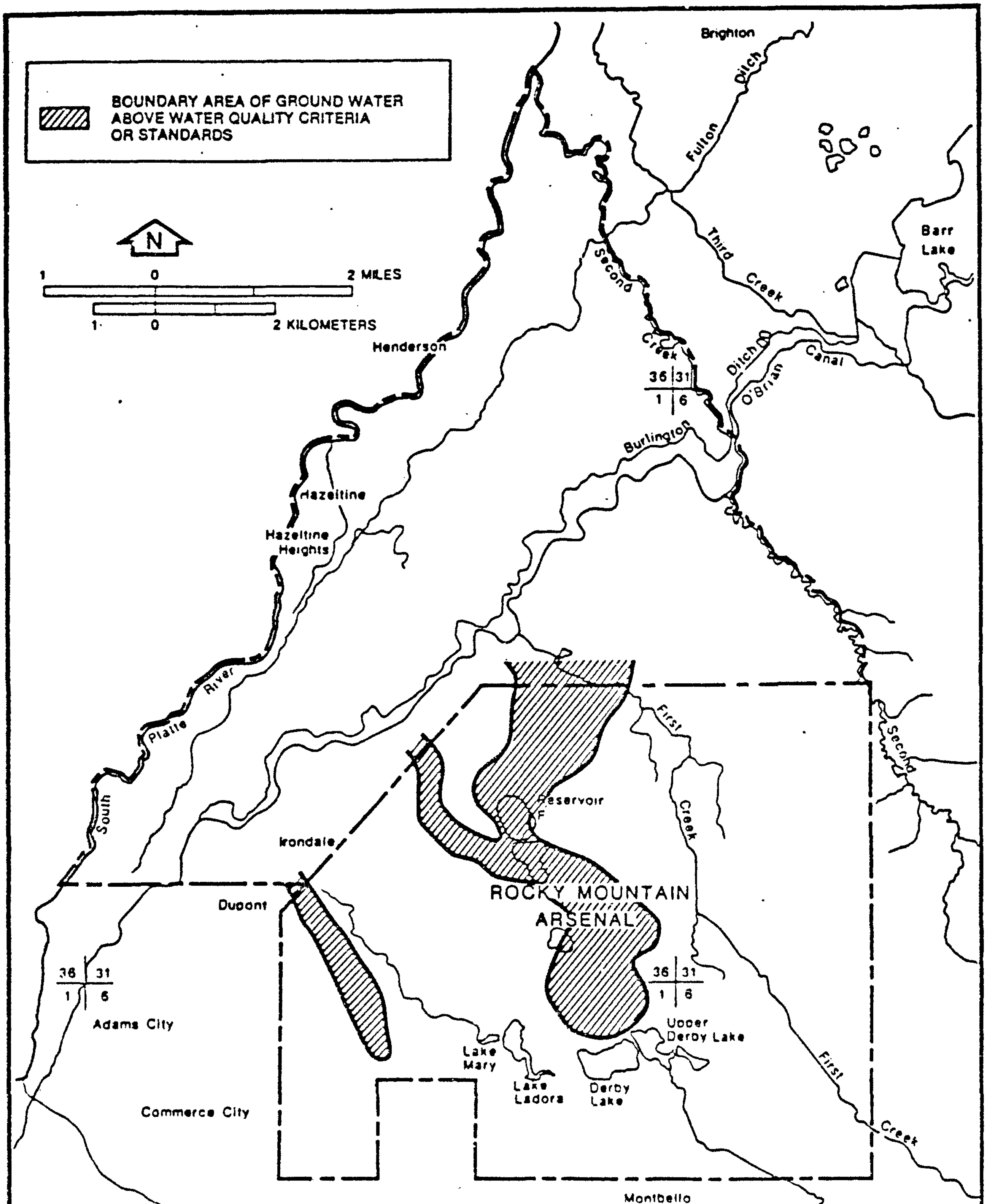

Figure 1.6-1
CHEMICAL PLUME ABOVE
ACCEPABLE LIMITS

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U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

The 360° Monitoring Program had been modified periodically since 1975. The number of wells sampled has been altered due to abandonment of selected wells and addition of new ground water monitoring wells. In 1985, the 360° Program sampled approximately 100 onpost and offpost ground water wells. Water samples from these wells were analyzed for DIMP, DCPD, DBCP, Cl, F, Mg, Ca, K, Na, nitrate, sulfate, alkalinity, specific conductivity and pH on a quarterly basis. The 360° Program also collected water level data from 490 monitoring wells on a quarterly basis. The 360° Monitoring Program has essentially been replaced by the Task 4 Monitoring Program.

1.6.1.2 RCRA Monitoring Program

Basin F is a RCRA hazardous waste facility and therefore must comply with appropriate RCRA regulations. During the first year of ground water monitoring, the Basin F RCRA program was in the Detection Monitoring Phase and all ground waters were analyzed for RCRA Detection Monitoring Program parameters. Contaminant migration from Basin F was reconfirmed during this monitoring effort. The Basin F monitoring program has progressed into the Compliance Monitoring Phase, with a specific list of contaminants being monitored in the 3 upgradient and 9 downgradient (12 total) monitoring wells. This list of analytes includes DIMP, DBCP, DCPD, aldrin, isodrin, endrin, dieldrin, oxathiane, dithiane, PCPMS, PCPMSO, $PCPMSO_2$, chloride, and fluoride.

1.6.1.3 Second Sources Monitoring Program

As a result of the detection of RMA contaminants offpost, there are three boundary control systems currently operating at RMA for the mitigation of these ground water pollutants. These include the Northwest Boundary Control System (NWBC), the North Boundary Control System (NBC), and the Irondale Containment System (IC). Three boundary control monitoring systems were developed in order to evaluate the performance of their respective boundary control systems.

North Boundary Control System

The North Boundary Control System (NBC) has been in operation for several years and includes a physical barrier (slurry wall) with both ground

water. Extracted ground water is treated by carbon adsorption water located upgradient of the slurry wall to intercept contaminated ground extraction and ground water injection wells. Dewatering wells are techniques. Treated water is recharged to the alluvium by use of both ground water injection wells and a recharge lagoon on the downgradient side of the slurry wall.

The NBC Monitoring Program consists of sampling 80 onpost and offpost wells in the Alluvial and Denver aquifers. Samples from these wells are collected on a quarterly basis, or more frequently if problems with the system arise or operational parameters are changed. All water samples collected from the monitoring network are analyzed for DIMP, DCPD, DBCP, endrin, dieldrin, isodrin, aldrin, oxathiane, dithiane, PCPMS, PCPMSO, $PCPMSO_2$, chloride and fluoride.

Northwest Boundary Control System

The Northwest Boundary Control System (NWBC) has been in operation for approximately one year. This containment system consists of both a physical barrier (slurry wall) and hydrologic barrier. Ground water extraction wells collect contaminated ground water which is treated by carbon adsorption prior to recharge.

The NWBC system monitoring system is composed of 45 onpost and offpost monitoring wells which are sampled on at least a quarterly basis. Water samples collected form these wells are analyzed for DIMP, DBCP, endrin, dieldrin, isodrin, aldrin, chloride, and fluoride.

Irondale Boundary Control System

Ground water is extracted, treated, and reinjected. The third boundary remediation system is the Irondale Contaminant System. The system is operated by Shell, which supervises collection and analysis of the water samples associated with its operation. This hydrologic control system installed at the southern portion of the northwest RMA boundary (Irondale System) does not contain a physical ground water barrier. This system consists of two rows of ground water dewatering wells and a single row of recharge wells downgradient of the extraction wells.

With the exception of the 360° Monitoring Program, the monitoring programs discussed above are currently in operation. In addition to these programs, there are a number of other programs that have been conducted in the past. These include the North Boundary Study, Pilot Containment System, Northwest Quadrant, and Nemagon Sampling Programs, all precursors to the various boundary control programs. There was also a Basin A Neck Program conducted to examine the feasibility of installing a barrier system in this area. In addition, several discrete investigations of the ground water quality at RMA were conducted during a short period of time. These programs were conducted by U.S. Army Waterways Experimental Station (WES) or Shell. Other water quality investigations were conducted by the RMA Environmental Division (RMA-ED) under the Basin F Study, Regional Sampling or Source Identification Programs.

As these ancillary programs are not currently operated and are not necessary under regulatory requirements, they will not be incorporated into the Task 4 sampling effort. However, information from these programs will be utilized for the well selection procedures discussed in Section 3.0 of this Technical Plan.

1.6.2 SURFACE WATER

Limited information is available on contamination of the surface waters at RMA. Preliminary analysis of water within First Creek indicated the presence of diethyl and dibutyl phthalates and cyclohexanone (RMA-CCPMT, 1983). Chloroform, dieldrin, DBCP, and DIMP have also been detected (USATHAMA Edgewood Scientific Computer Center data base). The flow of water in First Creek is fairly constant across RMA, but decreases toward the north. There appears to be interaction between water in First Creek and ground water, with ground water contributing to surface flow in some areas (e.g. south of RMA) and surface water recharging ground water in other areas (e.g. near the north boundary of RMA).

Within the Irondale Gulch drainage basin, the offpost storm drainages (Highline Lateral, Uvalda and Havana Interceptors) are considered free of RMA related contaminants (RMA-CCPMT, 1983), although DBCP and DIMP have

been detected in these areas in the past (USATHAMA Edgewood Scientific Computer Center data base). Two of the Lower Lakes have been sampled regularly for the past five years. Actual lake water is relatively clean; however, contaminants are found concentrated in lake bed sediments. Sediment contaminants include dieldrin and mercury.

The Basin A ditch, a minor flow route that conveys storm runoff from the South Plants Area to Basin A, has been found to contain high amounts of various contaminants. These include chloroform, trichloroethylene, tetrachloroethylene, toluene, xylene, ketones, and benzene (RMA-CCPMT, 1983). These compounds were probably derived from past spills on surface soils.

1.6.2.1 360° Monitoring Program

Surface water monitoring at RMA has been performed as part of the 360° Monitoring Program. Water samples were collected from 30 onpost and 4 offpost sites on a quarterly basis. Samples were analyzed for DIMP, DCPD, DBCP, Cl, F, Ca, K, Mg, Na, nitrate, sulfate, hardness, alkalinity, conductivity, and pH. Sampling points included various surface water features such as streams, ditches, lakes, and ponds.

In addition to water quality data, an integral part of the program was the collection and compilation of water quantity data. Flow and water level data were collected onpost weekly at eleven gaging stations and three lake sites. Additional measurements were recorded at two flow meters. Information was presented in monthly RMA Surface Water Balance Summaries.

1.7 SUMMARY OF TECHNICAL APPROACH

The purpose of this task is to perform a Water Quality/Quantity Survey for the onpost area of RMA. The scope of work includes selection of ground water monitoring wells and surface water locations to be sampled. Sampling location selection is followed by collection of surface water and ground water samples, measurement of appropriate field parameters, and chemical analysis of water samples. Finally, this data will be

evaluated to document the extent of contamination and verify the information in the existing data base.

1.7.1 SCOPE OF WORK

The purpose of the Task 4 Water Quality/Quantity Survey is to execute a one year ground water and surface water surveillance program capable of satisfying the various regulatory requirements, developing a litigation quality data base, and verifying the extent and nature of known contamination. In order to achieve these objectives five distinct technical elements are anticipated. These are as follows:

- Review historical data;
- Develop a monitoring program to achieve the above objectives;
- Execute the monitoring program utilizing litigation quality sampling and analytical procedures;
- Assess data quarterly for possible adjustments in the monitoring program; and
- Compile the accumulated data at the end of the one year program.

Currently there are over 2,000 monitoring wells on RMA. During the review of historical data, a large number of these wells were evaluated with respect to construction detail, sampling history, and location. Criteria for evaluating these wells are described in Sections 3.1.1.1 through 3.1.1.3.

Based on the results of the review of the historical data, a monitoring program was designed, resulting in an extensive Initial Screening Effort. Based on an evaluation of the results obtained during the Initial Screening, the proposed monitoring program for the third and fourth quarters will be designed and implemented.

All ground water monitoring wells and surface water sampling sites will be sampled using uniform sampling methodologies. Ground water and surface water samples will be analyzed for a predetermined list of analytes including numerous organic and inorganic parameters. Sample collection, measurement of field parameters, and analysis of samples will

be performed in accordance with USATHAMA Quality Control/Quality Assurance procedures. These procedures include collection of field quality control samples and decontamination of all sampling equipment.

2.0 EVALUATION OF BACKGROUND DATA

2.1 DATA COMPILATION

The project team anticipates that although a considerable effort has been made to review site specific background information on RMA surface water and ground water hydrochemistry, the proposed data gathering and review efforts will be an ongoing process. Numerous background documents were reviewed prior to preparation of this technical plan. However, during performance of ground water well screening and selection of surface water sampling locations the project team will assimilate a considerable volume of additional information. This data compilation effort will include literature and data review as well as tabulation of data obtained during the field reconnaissance performed prior to task activities.

2.1.1 SITE RECONNAISSANCE/MEETINGS

The initiation meeting for Task 4 was held in Denver on May 22, 1985. The purpose of this meeting was to allow the project team to discuss the scope of work and project objectives with USATHAMA personnel.

As a result of previous task orders the project team was familiar with key RMA personnel and operational procedures. Therefore, initiation meetings were devoted primarily to discussions of technical issues and schedules.

Due to familiarity of the project team with RMA, site reconnaissance was deemed unnecessary. This activity was performed during the ground water monitoring well screening activity. Site reconnaissance was utilized to verify the existence and location of wells prior to sampling activities. A reconnaissance of surface water monitoring structures was performed on June 25, 1985, to determine the necessary efforts required to recondition and repair existing monitoring facilities and structures.

2.1.2 LITERATURE/DATA BASE REVIEW

During preparation of this technical plan numerous documents detailing RMA hydrogeology, hydrology, and disposal history were reviewed. A

considerable portion of Task 4 background data is contained within the USATHAMA Univac Data Base. The project team will rely primarily on the USATHAMA data base for information, as this data has passed through USATHAMA data acceptance routines and in general contains all computerized data of concern for the performance of this task. However, some data will be obtained from RMA files and the RMA data base.

3.0 GEOTECHNICAL PROGRAM

The Task 4 geotechnical effort is directed to the acquisition of water quantity and quality data at RMA. As designed, the program provides the necessary activities to satisfy task objectives of:

- o Establishing a litigation quality data base;
- o Monitoring changes in the lateral and vertical extent of contaminant migration; and
- o Satisfying compliance requirements of regulatory programs.

The program implements a regional hydrologic surveillance network for monitoring ground and surface waters present on the installation. It is dynamic and may be modified, as required, in response to changes in scope and/or objectives.

3.1 GROUND WATER MONITORING PROGRAM

Task 4 ground water monitoring activities are twofold. Separate efforts have been established to realize both hydrological and water quality requirements of the ground water phase of the task. The program is designed following the technical elements established for the task and therefore satisfies overall task objectives. Geotechnical activities will consist of measurement of water levels and collection of water quality samples.

3.1.1 DESIGN

Existing information on monitoring well construction, sampling history, monitoring well location relative to plume configuration, and the requirements of existing RMA ground water monitoring programs were evaluated as the major criteria for sample program design. The information was used to:

- o Identify wells with suitable construction;
- o Identify wells with documented sampling histories;
- o Identify wells with optimum locations relative to plume boundaries, areas of greatest contaminant concentrations, and areas inferred to be devoid of ground water contamination; and

- Identify wells that are currently being utilized by compatible RMA ground water monitoring programs.

These criteria were utilized to achieve program objectives by selecting the appropriate ground water monitoring wells and wells for water level measurements. The evaluations were utilized for comparative purposes. All factors were considered in designing a monitoring well network which best allowed adequate well construction, comparison with historical data, compliance with regulatory requirements, and definition of contaminant plume locations.

The conceptual design used for the well selection process is shown in Figure 3.1-1. All onpost wells for which sufficient information existed were subjected to a construction evaluation. Wells passing this evaluation were subjected to sampling history and location evaluations. Results of the evaluations were integrated to perform the final well selection.

3.1.1.1 Well Construction Evaluation

Construction evaluation criteria were utilized to place ground water monitoring wells into acceptable, potentially acceptable, questionable, and unacceptable categories. The RMA Well Summary Report (DP Associates, 1985) summarizes current information on file with USATHAMA and RMA, and contains 1,568 individual data records for onpost ground water monitoring wells. Approximately one third of these wells were not evaluated with respect to construction as either the Well Summary Report contained insufficient information, borehole and well completion logs were not available, or the well had been previously abandoned. The number of wells falling into these categories are listed below.

Well with insufficient information	=	443
Abandoned Wells	=	96
Total Wells Evaluated	=	1,029
TOTAL		1,568

Approximately one half (222) of the incompletely documented wells were installed by Shell Chemical Company and neither borehole nor well

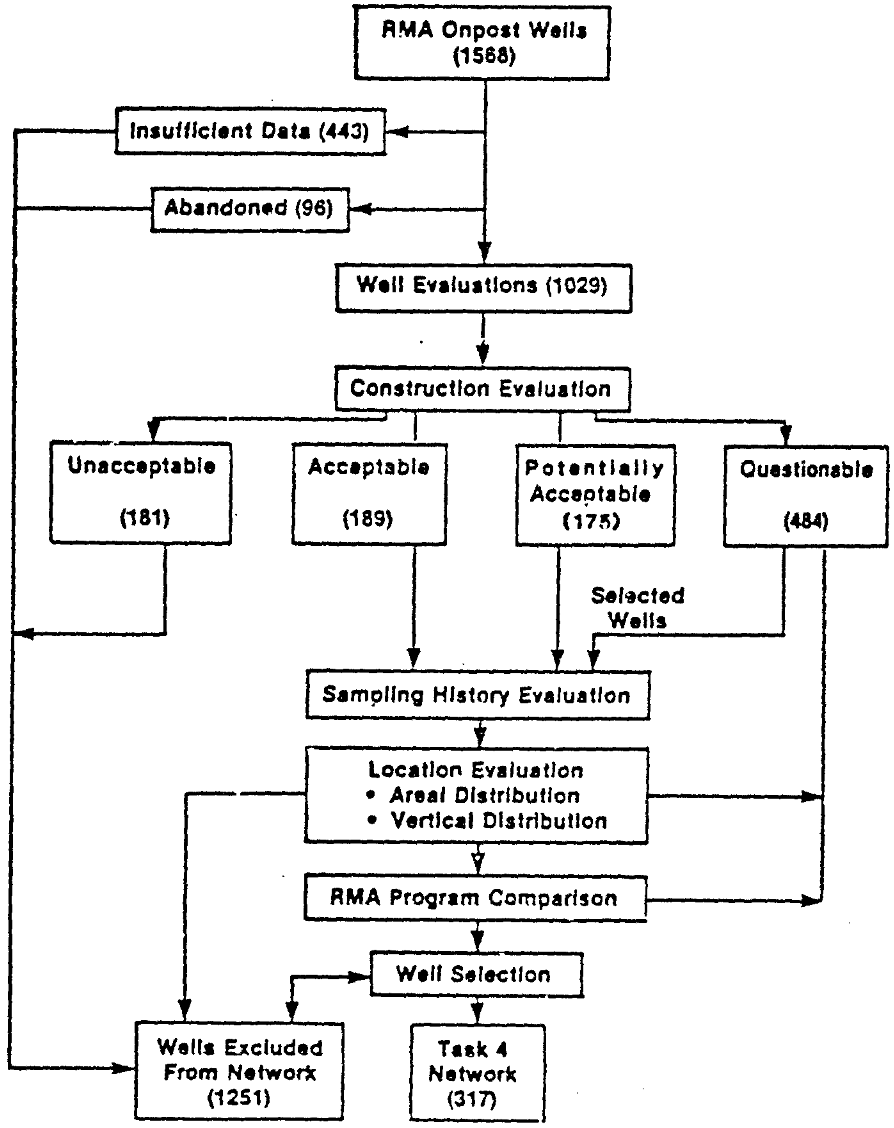

Figure 3.1-1
WELL SELECTION AND EVALUATION PROCESS

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U.S. Army P: .gram Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

construction logs were made available. Other wells were eliminated from consideration due to unclear or undocumented locations, unknown screened intervals, and undocumented borehole numbers.

Following elimination of the 539 wells that had inadequate documentation or were abandoned, a total of 1,029 ground water monitoring wells underwent detailed well construction screening.

Construction records of the remaining wells were evaluated in detail to determine the following:

- Drilling and completion procedures;
- Location and collar elevation accuracy;
- Casing cap and locking cap detail;
- Surface seal type and interval;
- Casing type and size;
- Blank interval backfill material;
- Screen type and length;
- Aquifer within the screen interval;
- Relation of the screen interval to water levels;
- Relation of the screen interval to aquifer thickness;
- Sand pack type and interval;
- Type and thickness of seal above sandpack;
- Relation of seal to aquifer limits;
- End plug and silt-trap detail; and
- Documentation of construction data.

Information was obtained from the USATHAMA and RMA data bases and from boring and well completion logs on file at the RMA Environmental Division. To expedite this evaluation and provide consistent results a standardized evaluation sheet was completed for each well (Table 3.1-1). These sheets were used for comparative purposes only and were not intended for use in ranking well constructions or eliminating individual wells.

The primary construction factor that influenced well suitability for either water sampling or water level measurements was the nature and

Table 3.1-1. Well Construction Factors (Page 1 of 2)

Section No.__________ Well No.__________

Construction Factors				
Aquifer	Upper (Alluvial)	Lower (Denver)	Both	Unknown
Location	Surveyed	Approximated From Map	Approximated In Field	Unknown
Collar Elevation	Surveyed	Approximated From Map	Approximated In Field	Unknown
Locking Cap	Yes	Secured Area	No	Unknown
Surface Seal Type	Grout	Bentonite	Soil	Unknown
Surface Seal Interval	≥10 ft	<10 ft	None	Unknown
Blank Interval Backfill	Grout	Soil	Sand	Unknown
Casing Type	Teflon/Stainless	Threaded PVC	Glued PVC	Unknown
Casing Size	≥6 in	4 inch	2-2.5 in	Unknown
Screen Type	Well Screen	Factory Slotted	Field Slotted	Unknown
Screen Length	>20 ft	10-20 ft	<10 ft	Unknown
Screen Interval	Sand	Sand/Clay	Clay	Unknown
Screened Zone	Full Penetration	Partial Penetration	Multiple Aquifer	Unknown
Relation to Water Level	Within Screened Interval	Above Screen	Below Screen	Unknown
Sand Pack Type	Industrial Sand	Pea Gravel	Natural	Unknown
Sand Pack Interval	Above Screen	At Top of Screen	Below Screen	Unknown
Seal Above Sand Pack	Grout	Bentonite	Soil	Unknown
Seal Above Sand Pack Interval	≥10 ft	<10 ft	None	Unknown
End Plug	Threaded	Glued	None	Unknown
Silt Trap	≥1 ft	<1 ft	None	Unknown
Construction Data	Detailed as Built Data	Approximate as Built Data	Work Plan	Unknown
Drilling Method	Auger	Rotary	Conductor Casing	Unknown

Table 3.1-1. Well Construction Factors (Continued, Page 2 of 2)

Section No.__________ Well No.____________

Evaluation

Data Reliability	Excellent	Good	Fair	Poor
Data Accuracy	≤ 1 ft	1-5 ft	>5 ft	Unknown
Recommendation for Monitoring	Acceptable	Possibly Acceptable	Questionable	Abandon
Usefulness for Specific Contaminants	Organic Monitoring	Inorganic Monitoring	Water Level	None
Recommendation for Water Level Measurement	Acceptable	Possibly Acceptable	Questionable	Abandon

Remarks:

Source(s) of Data:

Summary Prepared By:
Date Prepared:

Summary Checked By:
Date Checked:

in = inch
ft = feet

placement of the various seals. Lower confined aquifer wells without the minimum 10 ft thick bentonite or grout seal between the upper water table and lower confined aquifers, as required by the Colorado Division of Water Resources, were eliminated from further consideration. Denver Formation wells without a surface seal or with seals installed partially within the screened interval were eliminated.

A second major factor that affected the suitability of a well for water sampling was casing type. Stainless steel or Teflon® were preferred to other materials. Threaded PVC casing was considered for water sampling but was less desirable due to the potential for chemical interactions between certain ground water contaminants and plasticizers in the casing. Glued joint PVC casing was the least desirable of casing type and was primarily considered for water level measurements. In cases where no suitable wells for water quality sampling existed the glued PVC wells received consideration.

Screen placement was also considered in the evaluation. Wells with screens that intersected more than one aquifer were generally eliminated from consideration. This decision was made on a case by case basis depending on the nature of the water bearing units involved (i.e., confined or unconfined). Wells with screens that only partially penetrated an aquifer, or that did not intersect the water table (for unconfined zones) were considered less desirable sampling locations. These included most wells with screen lengths less than 10 ft. Wells that partially penetrated or wells with screens below the water table that were completed in a cluster configuration with other similar wells were retained due to their potential use in evaluating vertical stratification of, or within, a contaminant plume. Wells with screens placed in less permeable horizons were eliminated unless they were part of a cluster configuration. It was assumed that these wells would be difficult to sample due to their low yields and that adjacent wells with higher yields could satisfy program objectives. Overall, wells within the more transmissive portion of the aquifers were considered more suitable as they possessed a greater probability of producing water representative of the immediate area.

The final factor that affected selection was presence of the well cap. Only those wells with caps were considered for water quality sampling.

In addition to the above selection criteria, various other factors were considered which could affect the suitability of well for water sampling. These included the nature of the well screen (i.e., wrapped screen, factory slotted, field slotted, or perforated casing), type of sandpack (graded industrial sand, pea-gravel, caved material, etc.), drilling method, and presence of silt-trap and end plug. Such factors control the sediment content, well yield, and ability to produce samples with stable chemical conditions (i.e., pH, conductance, etc.). These criteria, in conjunction with factors previously discussed, control the amount of time required to obtain a sample, as well as the ability to purge the required number of casing volumes during evacuation prior to sampling.

Finally, a qualitative estimate of the reliability of the construction details based on the available documentation and a summary of the accuracy of the data were completed.

Results of the construction evaluation are summarized below.

Wells of acceptable construction	=	189
Wells of potentially acceptable construction	=	175
Wells of questionable construction	=	484
Wells of unacceptable construction	=	181
TOTAL		1,029

A large percentage (47%) of monitoring wells examined were of questionable construction. Wells were placed in this designation for one or more of the following reasons (Table 3.1-2):

- Completions cross hydrogeologic units, possibly allowing for cross-contamination or unreliable water level measurements;
- Discrepancies between the well summary report (DP Associates, 1985) and well completion data on the field boring logs; or
- Incomplete information on well construction detail.

Table 3.1-2. Ground Water Wells of Questionable Construction (484) (Page 1 of 2)

Section	Well Numbers
1	1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20
2	1, 2, 3, 4, 5, 6, 7, 8, 37
3	1
6	1, 2
7	1
8	2
11	1
12	1
19	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
20	1
22	2, 3, 4, 6, 8, 12, 13, 14, 15, 16, 17, 18, 19, 44, 51, 52, 54, 55, 57
23	2, 4, 8, 9, 10, 11, 13, 14, 15, 29, 32, 34, 35, 36, 39, 41, 42, 48, 47, 49, 52, 53, 54, 56, 57, 58, 59, 61, 63, 64, 66, 67, 96, 109, 110, 111, 118, 119, 120, 121, 122, 123, 128, 136, 137, 139, 140, 141, 142, 143, 144, 145, 146, 148, 149, 150, 151, 157, 158, 159, 160, 178, 199, 202, 206, 207, 209, 210
24	3, 6, 13, 25, 27, 47, 49, 53, 57, 58, 63, 80, 81, 83, 85, 86, 87, 89, 90, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 121, 122, 123, 124, 126, 127, 128, 129, 130, 135, 151, 165, 166, 167, 168, 169, 171, 177, 180, 181, 182, 186, 187
25	3, 5, 6, 7, 30, 31, 34
26	1, 2, 4, 5, 9, 11, 13, 14, 16, 18, 19, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 40, 41, 42, 43, 44, 45, 46, 47, 48, 50, 51, 52, 53, 54, 55, 56, 57, 58, 60, 61, 62, 63, 64, 65, 66, 67, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 96, 97, 119, 123, 124, 126, 127, 128, 129, 131, 132, 133, 136, 138, 139, 143, 144

Table 3.1-2. Ground Water Wells of Questionable Construction (484) (Continued, Page 2 of 2)

Section	Well Numbers
27	2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 15, 17, 18, 19, 25, 27, 28, 29, 30, 31, 32, 33, 34, 37, 40, 41, 42, 43, 44, 45, 49, 50, 51, 52, 63, 65, 75, 79, 80, 81, 82
28	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 14, 15, 16, 18, 20, 22, 23, 24, 27
31	2, 3
32	1
33	1, 2, 16, 18, 19, 20, 21, 22, 23, 24, 25, 53, 54
35	2, 3, 5, 6, 7, 8, 9, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 47, 48, 50, 51, 73, 74, 76
36	3, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 43, 48, 50, 55, 56, 57, 60, 61, 62, 63, 65, 66, 67, 68, 69, 72, 73, 74, 75, 76, 77, 78, 79, 81, 83, 84, 85, 86, 87, 88, 80, 90, 91, 103, 105, 107, 108, 109, 110, 145

Wells were defined to be of unacceptable construction for several reasons including the following (Table 3.1-3):

- o No supporting data could be found to verify the information contained in the well summary report (DP Associates, 1985);
- o No information on screened intervals existed on borehole or well completion logs;
- o Bentonite seals were improperly located within the screened interval; and
- o Confined bedrock aquifer wells were not sealed or otherwise properly isolated from the overlying water table aquifer.

Ground water monitoring wells found to be of acceptable construction are listed by section in Table 3.1-4. In general, the information for these wells is complete with minor exceptions. Wells were placed in this category if all or nearly all pertinent data were located and well construction detail indicated that the screened interval would provide a ground water sample representative of the adjacent aquifer materials. Many of these wells were installed in later years (1978 to present) during programs associated with the 1100 and 1200 series borings. In general, these wells possessed few data gaps with respect to construction and these gaps were considered to be insignificant with respect to the objectives of the construction evaluation (e.g., possession of a locking cap, etc.).

Wells found to be of potentially acceptable construction are listed by section in Table 3.1-5. Wells in this category lacked several pieces of information necessary to be considered acceptable. However, the data obtained suggested that the well was of adequate construction and the screened interval would produce a representative ground water sample. At a minimum, the location of the screened interval with respect to the alluvial-bedrock contact, saturated interval, and water table was appropriate. The placement and thickness of seals was considered adequate and well construction materials were of acceptable quality. As the number and placement of wells with acceptable construction was inadequate to achieve project objectives, all wells of potentially

Table 3.1-3. Ground Water Wells of Unacceptable Construction (181)

Section	Well Numbers
5	1
22	1, 9, 10, 32
23	3, 6, 38, 40, 49, 50, 55, 60, 62, 65, 95, 108, 127, 132, 151, 301, 302, 303, 304, 305, 330, 331, 332, 333, 334, 335
24	4, 7, 8, 9, 10, 28, 43, 45, 46, 48, 50, 51, 52, 54, 55, 64, 65, 84, 88, 91, 137, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438
25	1, 2, 27, 28, 33
26	6, 10, 15, 17, 20, 42, 49, 98
27	1, 8, 14, 16, 20, 21, 22, 23, 24, 26, 35, 36
28	10, 16, 17, 19, 21
30	1, 2
31	1, 4
33	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
34	1
35	1, 4, 10, 19, 24, 42, 43, 44, 45, 46, 49
36	2, 12, 37, 38, 39, 40, 41, 42, 44, 45, 46, 49, 53, 58, 59, 64, 70, 71, 82, 101, 102, 106

Table 3.1-4. Ground Water Wells of Acceptable Construction (189)

Section	Well Numbers
1	21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 32, 34, 35
2	9, 10, 11, 12, 13, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31
3	2, 3, 4, 5, 6, 7
4	7, 8, 9, 10, 11, 12
5	2, 3
6	3, 4, 5
7	4, 5
8	3, 4, 5
9	2, 3, 4
11	2, 4
12	2, 3, 4
19	14, 15, 16, 17, 18, 19
22	23, 24, 27, 28, 30, 31, 49, 60
23	177, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193
24	159
25	8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20
26	145, 146, 147
27	53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 73, 74, 76, 77, 78, 83
28	25, 28, 29
29	2, 3
30	3, 4, 5, 6, 7, 8, 9, 10, 11
31	5, 6, 7, 8, 9, 10, 11
32	2, 3
33	26, 27, 28, 29, 30, 31, 32, 33, 34, 35
34	2, 3, 4, 5, 6, 7, 8, 9, 10
35	52, 53, 54, 55, 56, 58, 59, 60, 61, 62, 63, 65, 66, 67, 68, 69, 70
36	1, 116, 118, 121

Table 3.1-5. Ground Water Wells of Potentially Acceptable Construction (175)

Section	Well Numbers
1	30, 33, 36, 37, 38, 39, 40, 41, 42, 43, 47, 48, 49, 50
2	14, 17, 32, 33, 34, 35, 36, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49
7	3
11	3
22	20, 21, 22, 25, 26, 29, 33, 34, 36, 37, 38, 39, 40, 41, 42, 43, 45, 53, 56, 58, 59
23	7, 28, 161, 166, 176, 196, 197, 198, 200, 201, 203, 204, 205, 211, 336, 337, 338, 339, 340, 341, 342
24	1, 2, 136, 149, 150, 158, 161, 162, 163, 164, 170, 171, 172, 173, 174, 175, 176, 178, 179, 183, 184, 185, 188, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354
25	4, 21, 22, 23, 24, 25, 26, 29, 35, 36, 37, 38, 39, 40
26	135, 140, 141, 142
27	64, 66, 68, 69, 70, 71, 72
28	26
33	48, 49, 50, 51, 52, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69
35	71, 72
36	112, 113, 114, 117, 119, 122, 136, 137, 138, 139, 140, 141, 142, 146, 147

acceptable construction were considered for inclusion into the monitoring network.

A total of 189 acceptable and 175 potentially acceptable wells were considered for inclusion in the proposed network. In order to fill gaps in the areal distribution of the acceptable and potentially acceptable wells, or to include wells with detailed sampling histories, wells of questionable construction were considered for inclusion into the network as necessary.

3.1.1.2 Sampling History Evaluation

Ground water monitoring wells which were considered to be of acceptable or potentially acceptable construction were subjected to a sampling history evaluation. In addition to these wells, sampling history evaluations were performed for all wells of questionable construction that were part of the 360° and RCRA Monitoring Programs. A sampling history evaluation was also performed for other wells of questionable construction that were considered for inclusion into the program as a result of the location evaluation and final selection process.

The purpose of this evaluation was not to eliminate wells from sampling but to identify monitoring wells that exhibit:

- Long term sampling histories;
- Elevated contaminant concentrations;
- Consistent contaminant concentrations;
- Trends in contaminant concentrations; and
- Erratic or anomalous chemistry.

Evaluation of these parameters would not eliminate wells from consideration, but rather would identify key wells and wells with anomalous or questionable results, and provide a basis for selection between wells with similar well constructions and locations.

Factors examined and documented for each well included the frequency of sampling, the period of record, the analytes determined, and well status with respect to current RMA Programs. Evaluation of chemical data

included the identification of contaminants detected, frequency and magnitude of this detection, and chemical trends. Contaminant trends were described as erratic (variable), increasing or decreasing, and consistently high or low. Contaminant trends were noted for all organic compounds and inorganics ions of significant to detectable concentrations.

Sampling procedures were also to be evaluated for each sampling event. However, upon consultation with RMA and USATHAMA personnel it was concluded that insufficient information was available to evaluate sampling methodology.

Based on the evaluation of prior sampling results, a number of general observations were identified. First, most wells exhibited consistent trends (increasing, decreasing, or constant) with respect to inorganic contaminants (Cl, F, SO_4) and organic contaminants of high solubility and low volatility. However, these same wells had a high tendency to exhibit variable concentrations for organic contaminants present at concentrations near the method detection limit and for organics with moderate volatility.

Variations in concentrations of organic contaminants near the method detection limits most likely result from inherent variability in the analytical techniques at low concentrations. Additionally, variations in the method detection limits achieved by each of the laboratories analyzing samples (RMA, CDH, TCH, and SCC) may have obscured definition of contaminant trends.

Erratic results for volatile and semi-volatile organic compounds is assumed to be at least partially a result of incomplete or inconsistent well purging techniques. Volatile organics will be air stripped from ground water by certain sampling procedures and also during atmospheric contact in the well bore. Sample handling and preservation techniques may also affect the quality of volatile and semi-volatile analytical results, however, there was no documentation available to evaluate this impact.

Ground water monitoring wells included in the 360° and RCRA Programs have long and detailed sampling histories. However, less than one half of these wells were considered acceptable or potentially acceptable with respect to well construction. In some cases no well construction data were available. Many of the wells installed in the early 1980's were found to have acceptable construction, but as these wells (1100 series) were relatively new only a short period of record was available for evaluation.

Many wells do not possess regular detailed sampling histories over a long period of record. For example, many wells were sampled on a semi-annual, quarterly or even more frequent basis for a period of one to two years. However, their remaining sampling histories display numerous gaps where these same wells were not sampled for several years. In many cases they were sampled with a different frequency (i.e., annually) several years later. Much of this variation in sampling histories apparently resulted from budgetary and manpower restrictions at RMA. However, these variations in sampling histories, along with those previously noted, prevented a straight forward interpretation of contaminant trends.

A final factor affecting definition of contaminant trends was the variation in analytes determined during successive sampling events. For example, in one year major ions were evaluated, several years later RMA organics were evaluated, and subsequently only pesticides were evaluated. In other cases, pesticides would be detected during a specific sampling event or sequence of events (i.e., four quarters in one year) but were not included in the analytical program for subsequent years. Again, these variations presumably resulted from budgetary and manpower restrictions at RMA.

The final step in the evaluation of the sampling history was to evaluate water level data obtained for each well. Information from the 360° Monitoring Program indicates that water levels in 490 wells were measured on a quarterly basis. The goal of this evaluation was to identify those wells that displayed consistent water levels, those that displayed rising or falling trends, and those that displayed seasonal

variations or irregular results. To support this evaluation, information was obtained on the period or record, frequency of past measurements and relation to current water level measuring programs.

To document the above, an evaluation sheet was prepared for each well (Table 3.1-6). For ease of tabulation during review of the analytical data, appropriate descriptions for each factor were denoted on these sheets. The data sheets were used to provide input to the summary evaluation and well selection process performed at the end of the data evaluation. It should be noted that unlike the well construction evaluation, no suitability screening occurred during the sampling history evaluation.

3.1.1.3 Location Evaluation

The final screening performed prior to selection of the ground water monitoring network was evaluation of the areal and vertical distribution in order to identify wells that had optimum locations relative to hydrogeologic and known contaminant conditions.

During this evaluation, individual well placements were examined to ensure that the most probable flow paths in and out of an area had been monitored, that areas with the greatest flux in and out of a section had been monitored, that background and worst case conditions had been evaluated, and that a sufficient density of wells existed to define the lateral extent of contamination.

The initial method for evaluating location was to examine the distribution of wells of acceptable or potentially acceptable construction with respect to aquifer distributions and ground water flow paths. Areas of insufficient coverage, incomplete transects across or along major flow paths, or areas with dense coverage outside of major flow paths (i.e. bedrock highs) were identified. Wells with questionable construction details in areas of insufficient coverage were included to complete the network of candidate wells. Areas of dense coverage were also identified

Table 3.1-6. Sampling History Data Affecting Selection Summary Sheet

Section No.________________ Well No.________________

Sampling History	Currently in Program		In Past Program	Infrequently Sampled	Sampled Once	Never Sampled
Sampling Program	360		NBC	NWBC	RCRA	Other
Sampling Frequency	Quarterly		Semi-Annual	Annual	Infrequent	Unclear
Period of Record	>5 years		1-5 years	<1 year	Once	Variable
Analytical Program	VOA's	PP's	RMA-Organics	RCRA	Drinking Water	Major Ions
Analytical Laboratory	RMA	CDH	TCH	Contract	Unknown	
Contaminants Detected	Cl	Fl	DIMP	DBCP	DCPD	Other Organics
Contaminant Trends (CH, CL, P, D, I, O)	Consistently High	Consistently Low	Contamination Increasing	Contamination Decreasing	Variable Results	No Contamination Detected
Well Evacuation	5 Casing Volumes		3 Casing Volumes	Field Stabilization	Bail Dry	Unknown
Evacuation Equipment	Bailer		Submersible Pump	Gas Driven Pump	Peristaltic Pump	Unknown
Sampling Equipment	Bailer		Submersible Pump	Gas Driven Pump	Peristaltic Pump	Unknown
Stabilization	Always Stabilizes		Generally Stabilizes	Rarely Stabilizes	Never Stabilized	No Data
Well Yield	≥1 gpm		0.5-1.0 gpm	<0.5 gpm	Runs Dry	No Data
Water Level Measurement	Currently Measured			Measured in Past	Continuously Measured	Never Checked
Frequency	Continuously			Quarterly	Infrequent	Once
Period of Record	>5 years			1-5 years	<1 year	Once Variable
Water Level Trends	Consistent			Rising	Falling	Variable Unknown

Remarks:

Source(s) of Data:

Summary Prepared By:
Date Prepared:

Summary Checked By:
Date Checked:

VOA = Volatiles/Purgeables
PP's = Priority Pollutants

Source: HLA, 1985.

The vertical distribution of wells with respect to aquifer configuration and ground water flow paths was also examined. This was performed primarily by identifying candidate wells that were part of well clusters and including additional members of the clusters from the list of wells with questionable constructions. Additionally, major clusters composed entirely of wells with questionable construction were identified and the merits of including these clusters were evaluated. Finally, the overall distribution of clusters was evaluated to identify areas of dense coverage or duplication of clusters.

The second step in evaluating location was to compare the distribution of candidate wells with the map of major contaminant sources (Figure 1.5-1). Well distribution was then reviewed with respect to its ability to define the impacts arising from each major source. Additional wells were selected from the list of wells with questionable construction, where insufficient coverage relative to upgradient, lateral, or downgradient water quality in the vicinity of the source was identified.

The areal distribution of wells was compared to known contaminant plumes (Figure 1.6-1), following the source review. Areas with insufficient longitudinal or transverse coverage relative to plume limits were identified and additional wells were again selected from the list of questionable constructions.

3.1.2 INITIAL SCREENING PROGRAM (ISP) MONITORING NETWORK

3.1.2.1 Selection of the Monitoring Wells

The selection of wells for the Initial Screening Program (ISP) monitoring network was based upon summary evaluations of well construction, sampling history, and location. Each summary evaluation included an examination of the follwoing:

- o Aquifer - upper or lower;
- o Well construction - good, potentially acceptable, unacceptable or unknown;
- o Sampling history - long term record, single sampling event, quarterly, yearly, etc.;

- Current programs - 360°, RCRA, NBC, NWBC, IC, or not currently monitored;
- Contaminants detected and contaminant trends; and
- Relation of the well to known contamination - upgradient, downgradient, within plume, lateral to plume, at source, etc.

A list of the selected wells was compared to the list of wells monitored by ongoing RMA programs to assess the degree to which each program could be incorporated into the Task 4 monitoring network. Where it appeared that the majority of an ongoing program could be incorporated, those wells that were required by the pre-existing RMA program, but were not included in the list of recommended wells for Task 4, were reevaluated. When possible, these additional wells were included in the Task 4 ISP or substituted for equivalent wells in the Task 4 list.

The second step of the summary evaluation was to examine the areal and vertical distribution of the proposed monitoring network. Maps were prepared showing the distribution of the proposed monitoring points for each aquifer. These distributions were evaluated for areal density, their relationship to known flow paths, and their relationship to known contaminant plumes and contaminant sources. Areas of insufficient coverage or excessive coverage were identified and additions or deletions to the proposed monitoring network were made as follows:

- In locations where contaminant plumes or contaminated sources were not in close proximity, individual wells or well clusters that are adjacent to other wells or clusters were examined. Deletions from the network for adjacent wells or well clusters were made based on sampling history and well construction. Sampling history factors included frequency of sample collection, contaminants detected, contaminant concentrations, and inclusion in current RMA programs. Well construction considerations included depth of the screened interval

(formation), screen length, and casing diameter. Preference was always given to the use of well clusters when feasible to obtain information on vertical stratification.

- In areas adjacent to contaminant sources or within contaminant plumes, deletions from the program were made as necessary to provide best plume cross sections and vertical stratification. Rationale is essentially identical to that discussed above but emphasis was placed on retaining all wells presently in the 360° Program. Preference was also given to wells oriented along transects perpendicular to the direction of contaminant transport. Such lines of wells will provide additional control on contaminant migration.
- In areas where contaminants have been detected at depth, preference was given to inclusion of well clusters. Alluvial wells associated with a cluster were rated as having questionable construction in many cases. Yet, other wells completed in the Denver Formation and located in the same cluster were of acceptable or potentially acceptable construction. In such cases, the alluvial well was included in the program to provide information on vertical distribution of contaminants. Wells which occur in clusters that do not include individual alluvial and Denver wells were generally deleted from the network. Clusters of 5 to 8 wells contained overlapping or continuous screened intervals in several instances. Reductions were generally made to include an alluvial, upper Denver, intermediate Denver, and lower Denver Formation well in the network. The majority of selected well clusters consisted of three monitoring wells. When possible, well clusters in sections considered uncontaminated were retained in the network to provide both background ground water chemistry data and water quality information for interpretation of ground water flow.

Once a monitoring network for the ISP had been developed, a sensitivity analysis was performed. Under this evaluation a specific number of wells (a percentage of the total number) would be tentatively eliminated from the proposed monitoring network. The remaining network would then be evaluated in terms of its ability to meet the Task 4 program objectives. This iterative reduction process was continued until the minimum number of wells required to meet the program objectives were identified.

The selected ground water monitoring network consisted of 317 wells designated for chemical sampling and 863 wells selected for measurement of static water levels. The 317 wells designated for sampling are listed in Table 3.1-7. A significant number of these wells were of acceptable (176) and potentially acceptable (57) construction. However, as a result of the addition of other wells in critical locations or with long term sampling histories, 80 wells of questionable construction were included in this program. A single well of unacceptable construction (05001) was also included in the program. This well was added as it was in the 360° Program and was the only alluvial well in Section 5. The well was considered unacceptable due to the lack of well construction detail. Three wells whose boring logs were not located were also added to the network. These wells (03008, 03009, and 03010) are located near the rail classification yard. They were installed in the 1200 series boring program and thus are probably of adequate construction. These wells have been included in the network, because no other wells were present in the alluvium in this area.

A final review of the ground water monitoring network was performed, including tabulation of wells by section, to achieve program balancing. The review included the plotting of wells in various stratigraphic horizons to ensure adequate coverage of the alluvium and various levels within the Denver Formation. Network wells are listed by section in Table 3.1-8. The table illustrates total wells per section and the associated distribution of these wells in various stratigraphic horizons. For purposes of this evaluation, the upper 10 ft of the Denver Formation are considered part of the alluvial aquifer. Intermediate Denver wells possess screens between 10 and 50 ft below the bedrock surface; Lower

Table 3.1-7. ISP Ground Water Monitoring Network
(Page 1 of 2)

Section	Total Wells	Well Numbers
1	21	8, 12, 14, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35
2	23	8, 9, 10, 11, 12, 13, 17, 18, 19, 20, 21, 22, 23, 24, 25, 30, 31, 34, 35, 36, 37, 38, 39
3	10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
4	6	7, 8, 9, 10, 11, 12
5	3	1, 2, 3
6	4	2, 3, 4, 5
7	4	1, 3, 4, 5
8	4	2, 3, 4, 5
9	3	2, 3, 4
11	3	2, 3, 4
12	3	2, 3, 4
19	6	14, 15, 16, 17, 18, 19
20	0	NONE
22	14	20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 49, 59, 60
23	24	7, 29, 39, 49, 142, 166, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193
24	10	1, 150, 158, 159, 170, 178, 179, 184, 185, 188
25	19	8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 38, 39, 40
26	31	11, 41, 65, 66, 67, 70, 71, 72, 73, 74, 75, 76, 83, 84, 85, 86, 91, 92, 93, 94, 127, 128, 129, 132, 133, 140, 141, 142, 145, 146, 147
27	17	3, 40, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 74, 75, 76, 77, 78

Table 3.1-7. ISP Ground Water Monitoring Network
(Continued, Page 2 of 2)

Section	Total Wells	Well Numbers
28	6	23, 25, 26, 27, 28, 29
29	2	2, 3,
30	6	3, 4, 5, 9, 10, 11
31	4	5, 6, 7, 8
32	3	1, 2, 3
33	23	2, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 60, 61, 62, 63
34	9	2, 3, 4, 5, 6, 7, 8, 9, 10
35	30	5, 12, 13, 16, 17, 34, 35, 36, 37, 38, 39, 52, 53, 54, 55, 56, 58, 59, 60, 61, 62, 63, 65, 66, 67, 68, 69, 70, 71, 72
36	29	1, 65, 66, 69, 75, 76, 82, 83, 84, 90, 91, 109, 110, 112, 113, 114, 116, 117, 118, 119, 121, 122, 136, 137, 138, 139, 140, 141, 142
TOTAL	317	

Table 3.1-8. Summary of ISP Monitoring Well Description by Section

Section	Total	Number of Clusters	Alluvium	Intermediate Denver	Lower Denver
1	21	5	10	5	6
2	23	8	8	7	8
3	10	2	6	1	3
4	6	2	2	1	3
5	3	1	0	2	1
6	4	1	2	1	1
7	4	1	2	1	1
8	4	1	2	1	1
9	3	1	1	1	1
11	3	1	2	1	0
12	3	1	1	1	1
19	6	2	1	2	3
20	0	-	-	-	-
22	14	3	8	3	3
23	24	5	14	5	5
24	10	1	9	1	0
25	19	6	6	9	4
26	31	10	15	12	4
27	17	3	11	3	3
28	6	2	3	2	1
29	2	1	0	1	1
30	6	2	3	2	1
31	4	1	2	1	1
32	3	1	1	0	2
33	23	6	15	5	3
34	9	3	3	5	1
35	30	8	10	12	8
36	29	7	17	7	5
TOTALS	317	85	154 (49%)	92 (29%)	71 (22%)

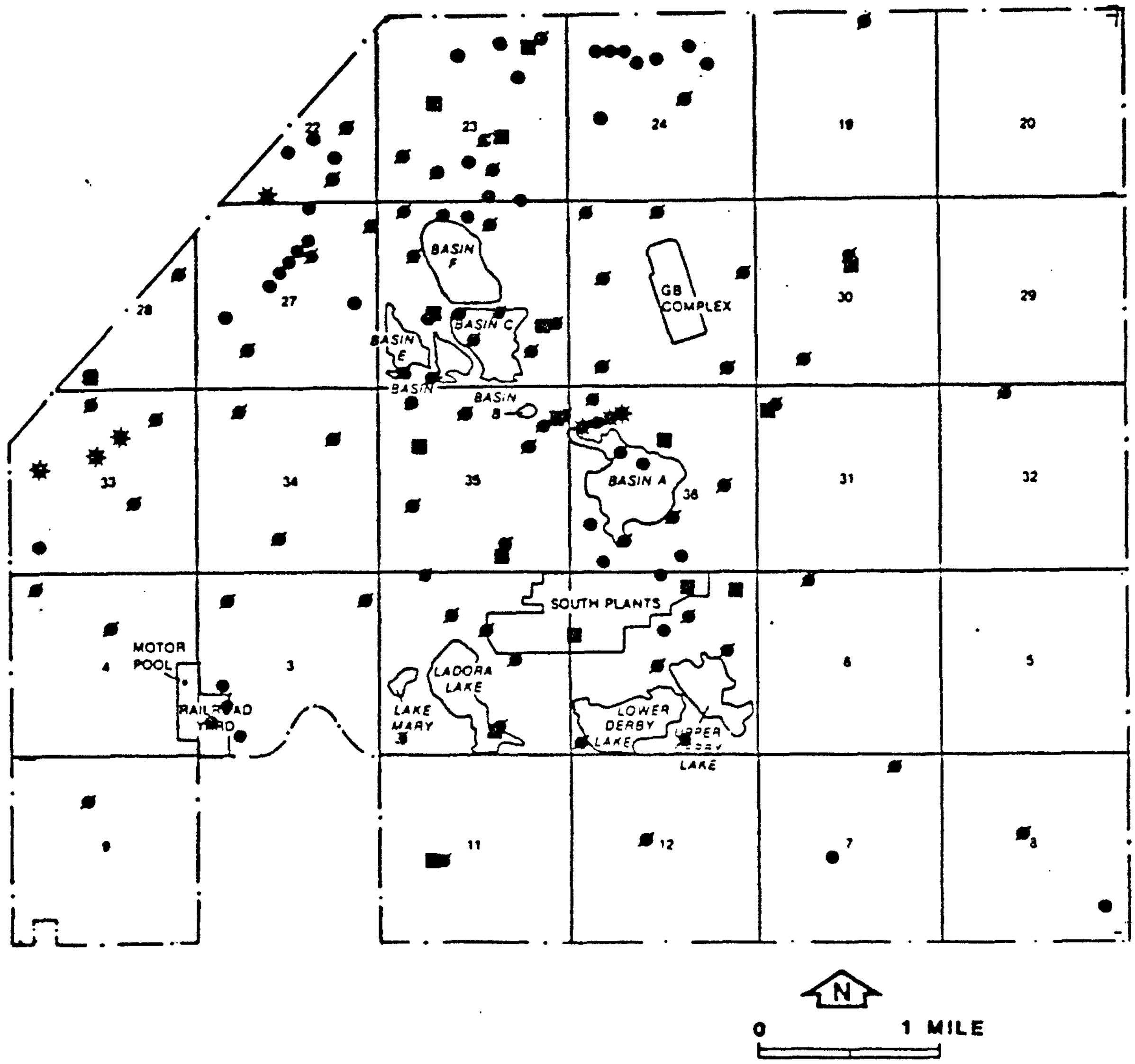
Denver wells possess screens greater than 50 ft below the bedrock surface. Of the 317 wells, 249 are associated with 85 cluster configurations included in the program.

Areal distribution of wells in each of the stratigraphic horizons indicated in Table 3.1-8 are shown in Figures 3.1-2 through 3.1-4 for alluvium, intermediate Denver, and lower Denver respectively. Figure 3.1-2 shows a widespread distribution of alluvial wells with highest well densities adjacent to and downgradient from known contaminant sources. Figure 3.1-3 shows areal distribution of wells in the intermediate Denver Formation. The intermediate Denver is probably semi-confined, and has the potential to be continuous with the alluvial aquifer through connections along weathered horizons or sand lenses. Figure 3.1-4 shows distribution of wells in the lower Denver Formation. Highest well densities are located in sections containing contaminant sources, so that the potential for contamination of multiple aquifer systems can be evaluated.

Figure 3.1-5 shows the distribution of alluvial wells with respect to configuration of the water table and major ground water flow paths beneath RMA. All major ground water flow paths have been covered.

Well distribution was examined with respect to source areas and contaminant plumes prior to finalization of the ISP. The highest well densities occurred in Sections 26, 35, 36, 23, 33, 1, and 2 (Table 3.1-8). These sections either contain known source areas or are located adjacent to RMA boundaries where contaminant plumes are migrating. Approximately one half of the wells are completed in the alluvium. Remaining wells are split between the intermediate and lower levels of the Denver Formation. Figure 3.1-6 displays the distribution of alluvial and shallow Denver wells with respect to primary contaminant sources and contaminant plumes at RMA. All primary contaminant sources are surrounded by both upgradient and downgradient wells. In addition, well distributions transect each known contaminant plume. Vertical clusters completed within each plume have also been included.

Table 3.1-12. Well [illegible]



EXPLANATION

- ● Single Alluvial Well
- Alluvial Well Paired With Bedrock Well(s)
- ✱ Multiple Alluvial Wells in Vertical Cluster
- ■ Upper Denver Well

Figure 3.1-2
GROUND WATER SAMPLING
NETWORK ALLUVIAL WELLS
ROCKY MOUNTAIN ARSENAL

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

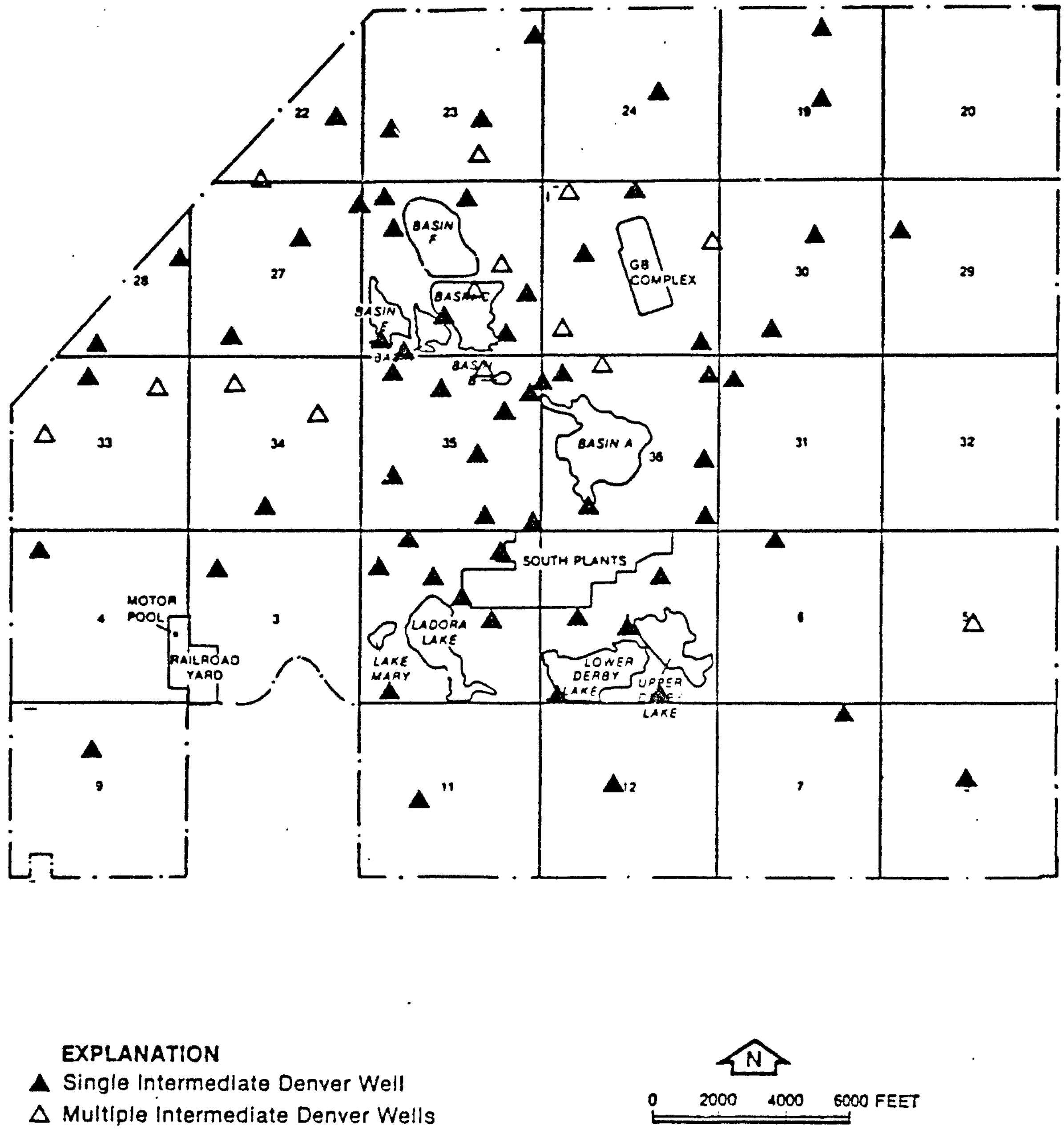


Figure 3.1-3
GROUND WATER SAMPLING NETWORK
INTERMEDIATE DENVER WELLS
(10-50 FEET BELOW CONTACT)
ROCKY MOUNTAIN ARSENAL

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

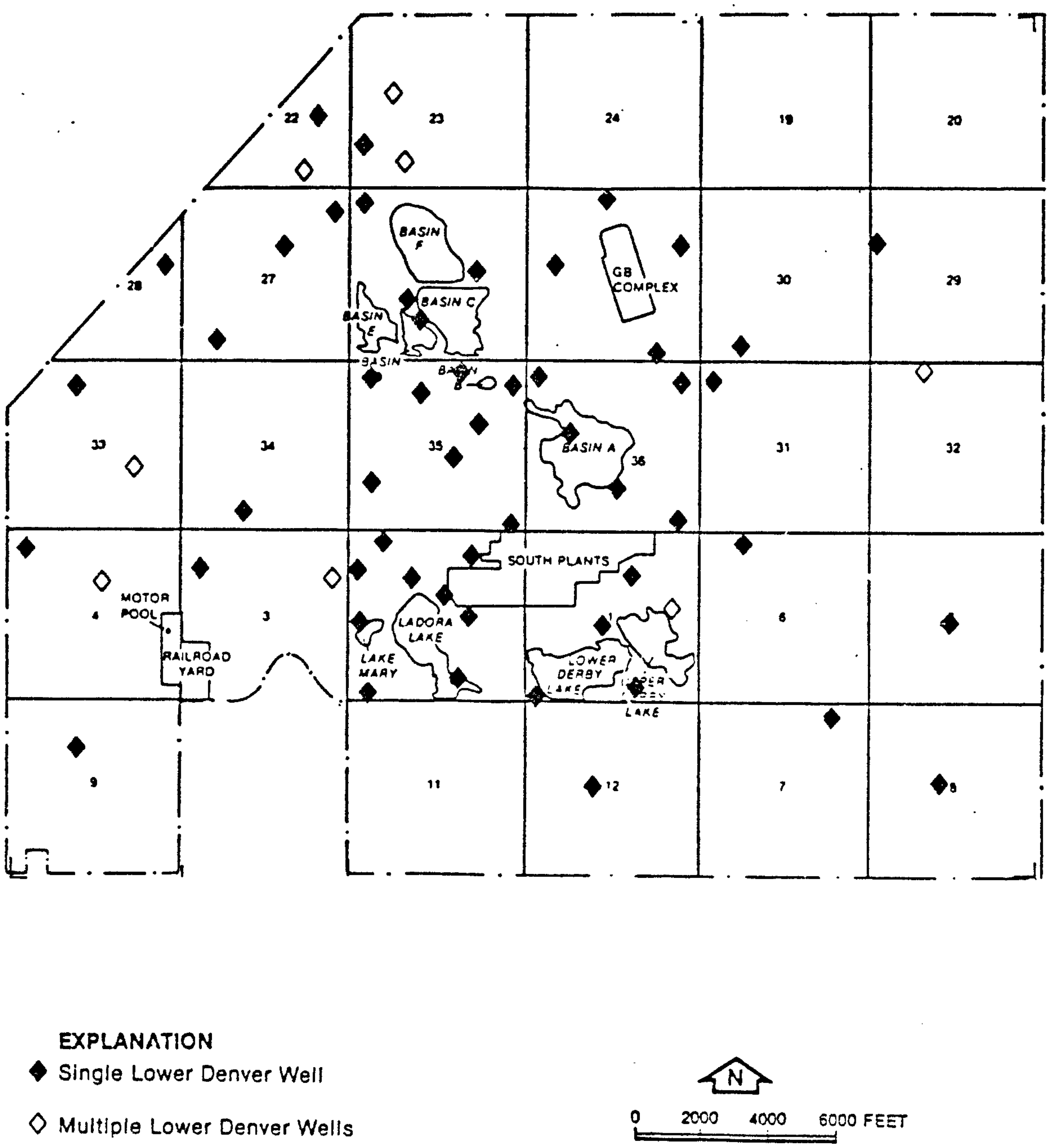


Figure 3.1-4
GROUND WATER SAMPLING NETWORK
LOWER DENVER WELLS
(> 50 FEET BELOW CONTACT)
ROCKY MOUNTAIN ARSENAL

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

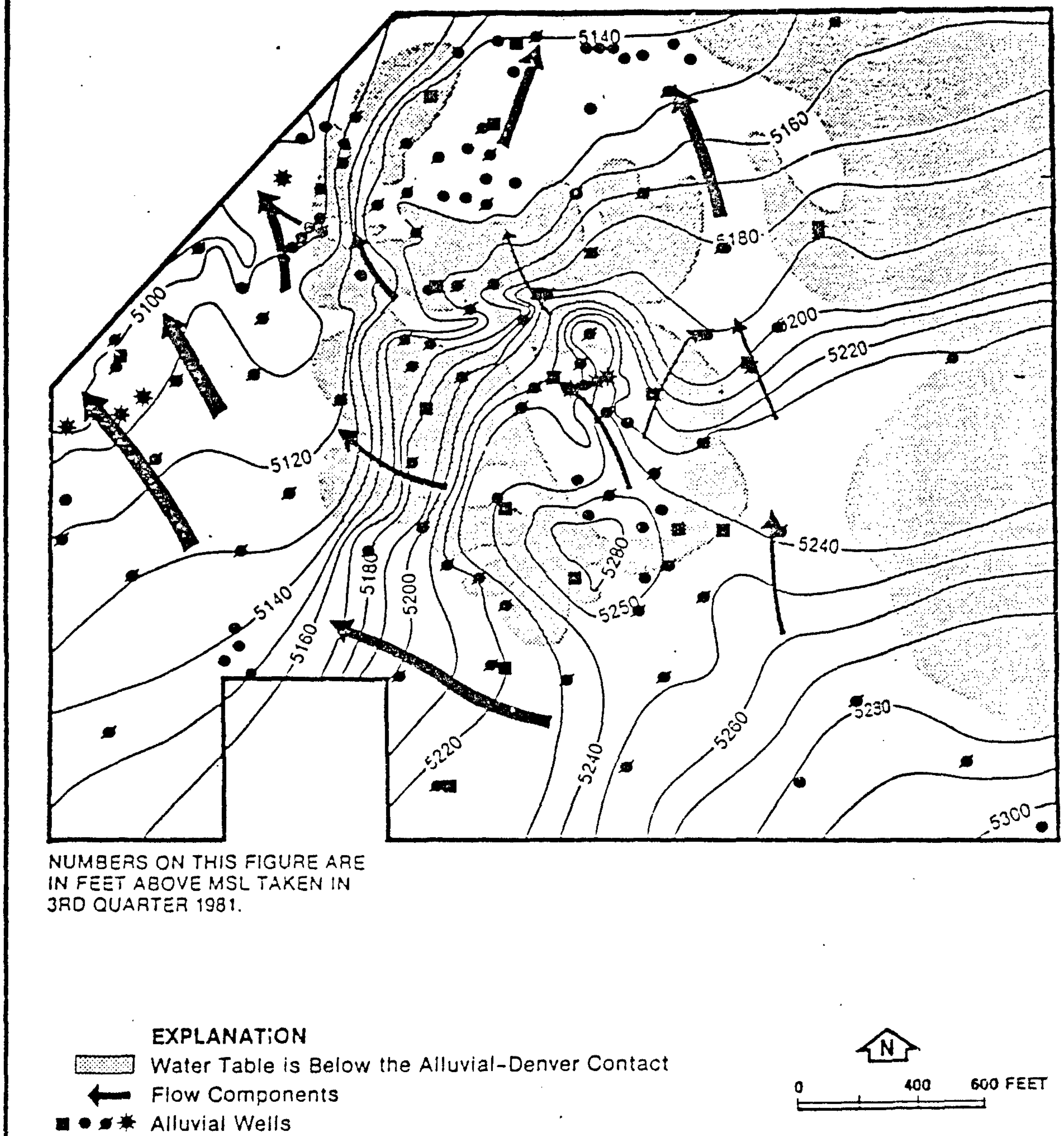


Figure 3.1-5
RELATIONSHIP OF ALLUVIAL GROUND WATER WELLS TO WATER TABLE AND FLOW COMPONENTS AT ROCKY MOUNTAIN ARSENAL

SOURCE: HARDING LAWSON ASSOCIATES, 1985

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

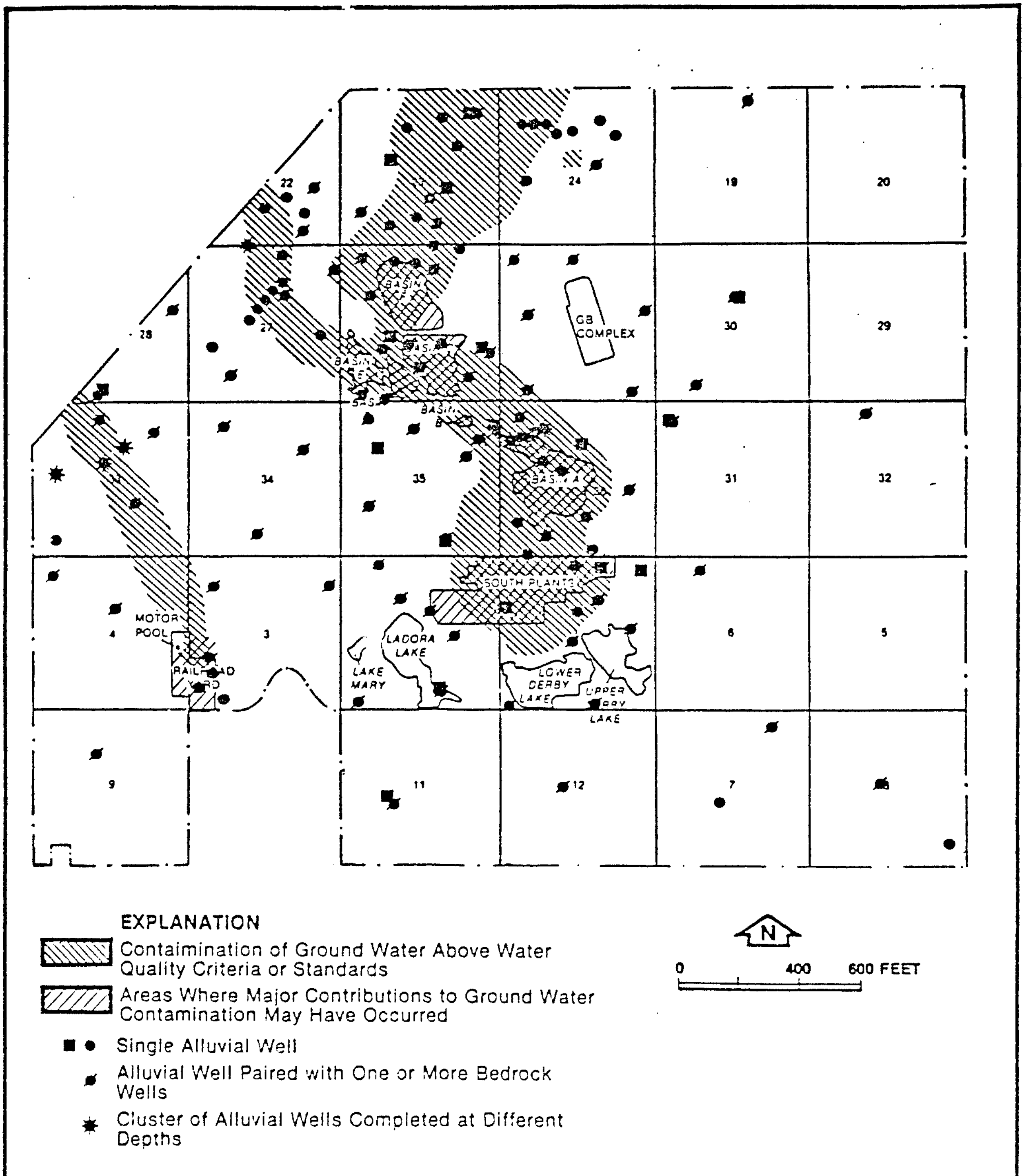


Figure 3.1-6
RELATIONSHIP OF ALLUVIAL GROUND WATER WELLS TO KNOWN CONTAMINANT PLUMES AT ROCKY MOUNTAIN ARSENAL

SOURCE: HARDING LAWSON ASSOCIATES, 1985

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

3.1.2.2 Modification to the ISP Monitoring Network

Modifications were made to the ISP at the request of PMO-RMA before finalization of the monitoring network. These revisions included the addition of 31 wells for a one-time only sampling program, 6 current RCRA wells, 3 newly installed wells, and 1 mislabeled well. In addition, 148 wells were designated for metals analysis.

One-Time Only Wells

A total of 31 wells from Sections 3, 4, 9, and 33 were added to the monitoring network. Wells were to be sampled using the same procedures as the other network wells, but were to be analyzed for purgeable organic parameters and DBCP only. One-time only wells were added to the program to provide further definition of potential volatile organic contamination along the western boundary of RMA.

One-time only wells were selected by examining all wells located in Sections 3, 4, 9, and 33. The first step in developing the one-time only network was to include all wells in these sections for which construction data were available. The areal distribution of these wells, along with wells previously included in the ISP, was then evaluated. Areas of excessive or inadequate coverage were identified. Selected wells were eliminated from the one-time only network in areas of excessive coverage to provide distribution equivalent to that proposed for the remainder of the one-time only sampling area. For areas with inadequate coverage, wells with no construction records were included.

RCRA Monitoring Wells

Evaluation of the current RCRA monitoring network wells at Basin F indicated that six of the twelve wells were unacceptable for inclusion into the Task 4 program. In response, six substitute wells were proposed. It was later determined that substitutions could not be made at the time, and that the original six RCRA monitoring wells would have to be sampled.

Mislabeled Well

Well 36048 was inadvertently sampled as a result of a misprinted sample label. Part of the original network, well 36084, was issued a set of sample labels identified as 36048. As a result, 36048 was sampled. Upon recognition of the error, a corrected set of labels were prepared and 36084 was sampled.

New Wells

As part of the investigation to define potential volatile organic contamination along the western boundary of RMA, three wells, 09005, 09006, and 09007 were installed in the area of the Bulk Mail Terminal. These wells were sampled as part of Task 4.

Monitoring Wells from Which Metals Fractions were Collected

Metals were not selected as parameters for analysis under the guidelines set forth in the original Task 4 Technical Plan. However, after the initiation of sampling, a decision was made to collect metals sample fractions from all the monitoring wells. These fractions were preserved and stored at the ESE-Denver laboratory to be available for future analysis. The revised program was initiated in the field and crews were instructed to collect appropriate metals fractions.

The collection of metals fractions was discontinued after approximately four weeks of sampling when a decision was made that no metals analyses would be performed during the ISP. No metals fractions were collected during the six weeks that followed.

Metals fraction analyses were reincorporated into the ISP upon recommendations by the PMO-RMA. A set of metals analytical parameters was chosen. Selected parameters (Table 3.1-9) included ICP analyses for the NF fraction plus individual determinations for mercury, nitrate-nitrite, and sulfate. A well monitoring network for metals analyses (Table 3.1-10) was developed based on the following priorities:

Table 3.1-9. Parameters Selected for Metals Analyses

NF Fractions	Additional Fractions
Calcium (Ca)	Mercury (Hg)
Potassium (K)	Nitrate-Nitrite (N)
Magnesium (Mg)	Sulfate (SO_4)
Sodium (Na)	Arsenic (As)
Zinc (Zn)	
Chromium (Cr)	
Cadmium (Cd)	
Lead (Pb)	
Copper (Cu)	

Table 3.1-10. Initial Ground Water Monitoring Network for Metals Analyses

Section	Total Wells	Well Numbers
1	11	8, 21, 22, 23, 29
2	9	8, 17, 30, 31
3	5	1, 2, 3, 5, 8
4	2	7, 10
6	4	2, 3, 4, 5
7	1	1
8	3	3, 4, 5
9	3	2, 3, 4
11	3	2, 3, 4
12	3	2, 3, 4
19	2	17, 18
22	4	22, 29, 30, 60
23	12	7, 29, 49, 142, 182, 183, 185, 186, 187, 191, 192, 193
24	4	1, 158, 159, 179
25	11	11, 15, 16, 17, 18, 22, 23, 24, 38, 39, 40
26	20	11, 41, 70, 71, 72, 73, 74, 75, 83, 84, 85, 86, 127, 128, 129, 132, 133, 145, 146, 147
27	5	53, 59, 60, 61, 76
28	3	23, 25, 26
29	1	2
30	3	9, 10, 11
31	1	5
32	1	1
33	8	22, 25, 26, 27, 30, 31, 33, 63
34	3	2, 5, 6
35	17	12, 13, 16, 17, 34, 38, 52, 54, 58, 59, 60, 61, 62, 65, 66, 67, 68
36	13	1, 76, 82, 83, 84, 90, 91, 109, 110, 112, 113, 114, 136
TOTAL*	115	

*TOTAL includes three alternates to allow for wells that may be dry or obstructed.

- Wells in which metal contaminants had previously been detected;
- Wells with previous data on metals concentrations;
- Wells required to provide an adequate areal distribution throughout each saturated horizon (i.e., alluvium, intermediate Denver, and lower Denver);
- Wells in a cluster configuration with other wells selected for metals analyses; and
- Wells from which metals fraction samples had previously been collected under Task 4.

The metals program was reinstituted in the field with crews again collecting appropriate metals fractions. However, it was later determined that this volume of the sample being collected was insufficient for complete analysis. As a result, a revised well network was generated to meet the project objectives regarding the number of wells required for metals analyses. The proposed network was developed from monitoring wells which had not yet been sampled. The network experienced a third revision based on the five criteria previously listed while minimizing resampling efforts and utilizing as many of the previously collected metals samples as possible. The final network is summarized in Table 3.1-11.

Final Sampling Network

As a result of modifications, 41 additional monitoring wells were added to the program. The final number of wells included in the initial screening effort was 358 of which 148 were selected for metals analysis. This total includes 31 one time only wells, 6 RCRA monitoring wells, 3 newly installed wells and 1 inadvertently sampled well.

3.1.2.3 Water Level Measurement Network

A process similar to that utilized for selecting sampling wells was utilized to devise a well network for water level measurements. Beginning with the monitoring wells included in the ISP, additional wells were selected from the list of those with constructions suitable or potentially suitable for water level measurements. Emphasis was placed on wells for which water levels were being obtained as part of ongoing RMA programs.

Table 3.1-11. Final Ground Water Monitoring Network for Metals Analyses

Section	Total Wells	Well Numbers
1	12	8, 12, 17, 20, 21, 22, 23, 27, 28, 29, 30, 31
2	8	8, 9, 10, 17, 20, 21, 30, 31
3	7	1, 2, 3, 5, 6, 7, 8
4	4	7, 10, 11, 12
5	0	NONE
6	0	NONE
7	0	NONE
8	3	3, 4, 5
9	2	2, 4
11	0	NONE
12	3	2, 3, 4
19	3	14, 15, 16
22	4	22, 29, 30, 60
23	10	39, 49, 142, 166, 182, 183, 184, 191, 192, 193
24	4	1, 158, 159, 170
25	9	18, 19, 20, 22, 23, 24, 38, 39, 40
26	17	11, 412, 70, 71, 72, 83, 84, 85, 86, 127, 128, 129, 132, 133, 145, 146, 147
27	7	53, 56, 58, 59, 60, 61, 76
28	3	23, 25, 26
29	0	NONE
30	0	NONE
31	0	NONE
32	3	1, 2, 3
33	9	22, 25, 26, 27, 30, 31, 32, 33, 63
34	6	2, 3, 4, 5, 6, 7
35	17	12, 13, 16, 17, 34, 38, 52, 54, 58, 59, 60, 62, 65, 66, 67, 68, 69
36	16	1, 65, 76, 82, 83, 84, 90, 91, 109, 110, 112, 113, 114, 137, 138, 141
TOTAL	148	

In addition to wells measured by the RMA 360° Monitoring Program, emphasis was placed on clustered wells completed at discrete depths. Measurement of water levels in clustered wells will allow a determination of vertical hydraulic gradients and evaluation of contaminant migration pathways.

Once the initial set of wells was identified using the above criteria, the areal distribution of the wells was examined using the maps prepared during the location evaluation (Section 3.1.1.3). Additional wells were then added to the program to ensure:

- o Adequate areal coverage of the alluvial and Denver aquifers;
- o Adequate areal coverage of both the highly permeable alluvium and less permeable weathered bedrock portions of the unconfined aquifer;
- o Best possible coverage of the Denver sands;
- o Coverage of all major flow paths within the alluvial aquifer;
- o Evaluation of spatially variable saturated thickness in the alluvial aquifer; and
- o Adequate coverage in the vicinity of all potential sources of ground water mounding (i.e., South Plants area, Basin A, etc.).

As with the design of the water sampling program, the merits of deleting and retaining individual wells were evaluated. The effects of the proposed reductions were then evaluated in terms of overall program objectives, deletion of wells from ongoing RMA programs, definition of flow paths, and resolution of anomalous areas.

Tables 3.1-12 and 3.1-13 summarize the 851 wells included in the water level measurement network. Figure 3.1-7 shows the distribution of alluvial and upper bedrock wells relative to the aquifer units and ground water flow paths. Figures 3.1-8 and 3.1-9 show the distribution of intermediate Denver wells and lower Denver wells, respectively.

3.1.2.4 <u>Comparison of ISP to Other RMA Ground Water Programs</u>

As described above, objectives of the Task 4 monitoring network are inconsistent with objectives of preexisting programs designed for

Table 3.1-12. Well Network for Alluvial Aquifer Water Level Measurements (Page 1 of 3)

Section	Total Wells	Well Numbers
1	28	1, 2, 4, 8, 9, 10, 11, 12, 16, 17, 18, 19, 20, 21, 24, 27, 30, 33, 38, 41, 44, 49, 501, 510, 514, 528, 537, 568
2	16	1, 7, 8, 11, 14, 17, 20, 21, 23, 26, 27, 33, 34, 37, 520, 580
3	13	1, 2, 5, 8, 9, 10, 516, 517, 518, 519, 522, 523, 526
4	31	2, 4, 7, 8, 10, 13, 14, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 524, 525, 527, 528, 529, 532
5	0	None
6	2	2, 3
7	2	1, 3
8	2	2, 3
9	2	1, 2
11	2	2, 3
12	2	1, 2
19	10	1, 3, 4, 5, 6, 7, 8, 9, 10, 14,
20	0	None
22	26	3, 4, 5, 6, 8, 12, 14, 16, 17, 18, 19, 20, 21, 22, 25, 29, 45, 49, 50, 51, 52, 53, 54, 56, 59, 60
23	96	2, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 26, 29, 34, 36, 37, 39, 43, 44, 45, 46, 47, 48, 49, 51, 52, 53, 56, 57, 58, 59, 61, 63, 64, 66, 67, 72, 79, 85, 92, 96, 101, 102, 106, 107, 109, 110, 111, 118, 119, 120, 122, 123, 125, 128, 129, 130, 131, 134, 135, 136, 137, 139, 140, 141, 142, 143, 144, 145, 146, 148, 149, 150, 157, 160, 161, 166, 176, 178, 179, 182, 185, 188, 189, 191, 196, 197, 198, 199, 204, 205, 208, 211, 342

Table 3.1-12. Well Network for Alluvial Aquifer Water Level Measurements (Continued, Page 2 of 3)

Section	Total Wells	Well Numbers
24	64	1, 2, 3, 6, 11, 24, 49, 57, 63, 80, 81, 82, 83, 85, 87, 89, 90, 93, 94, 95, 96, 97, 98, 99, 100, 101, 103, 105, 106, 107, 108, 110, 111, 112, 113, 114, 115, 117, 121, 122, 123, 126, 127, 128, 135, 150, 158, 161, 162, 163, 164, 165, 166, 169, 170, 176, 178, 179, 180, 181, 182, 184, 185, 188
25	9	8, 11, 15, 18, 22, 30, 32, 35, 38
26	46	1, 2, 4, 5, 7, 8, 9, 11, 13, 16, 18, 19, 20, 24, 26, 40, 41, 44, 45, 47, 48, 50, 62, 63, 65, 68, 70, 71, 73, 74, 76, 78, 81, 83, 85, 87, 88, 91, 93, 124, 127, 132, 133, 143, 144, 145
27	50	2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 15, 17, 19, 25, 28, 30, 32, 34, 37, 40, 41, 42, 43, 44, 45, 50, 51, 53, 56, 59, 62, 63, 64, 66, 68, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83
28	23	1, 2, 3, 5, 6, 7, 8, 9, 11, 12, 14, 15, 18, 20, 21, 22, 23, 24, 27, 28, 30, 503, 513
29	1	2
30	4	3, 4, 6, 9
31	6	2, 3, 5, 6, 9, 10
32	1	1
33	65	1, 2, 4, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 30, 33, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 54, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 500, 501, 502, 505, 506, 507, 508, 509, 510, 511, 512, 514, 530, 531, 533, 534, 576, 577, 579, 580, 582
34	4	2, 5, 8, 515
35	22	5, 6, 7, 14, 18, 23, 25, 26, 30, 31, 34, 37, 40, 47, 48, 52, 53, 58, 61, 65, 66, 69

Table 3.1-12. Well Network for Alluvial Aquifer Water Level Measurements (Continued, Page 3 of 3)

Section	Total Wells	Well Numbers
36	49	1, 10, 13, 17, 24, 29, 43, 50, 54, 56, 60, 63, 65, 67, 68, 69, 73, 74, 75, 76, 77, 81, 82, 84, 85, 86, 87, 89, 90, 91, 92, 93, 99, 103, 109, 112, 123, 128, 134, 135, 136, 137, 138, 139, 140, 141, 142, 145, 146

Total: 576

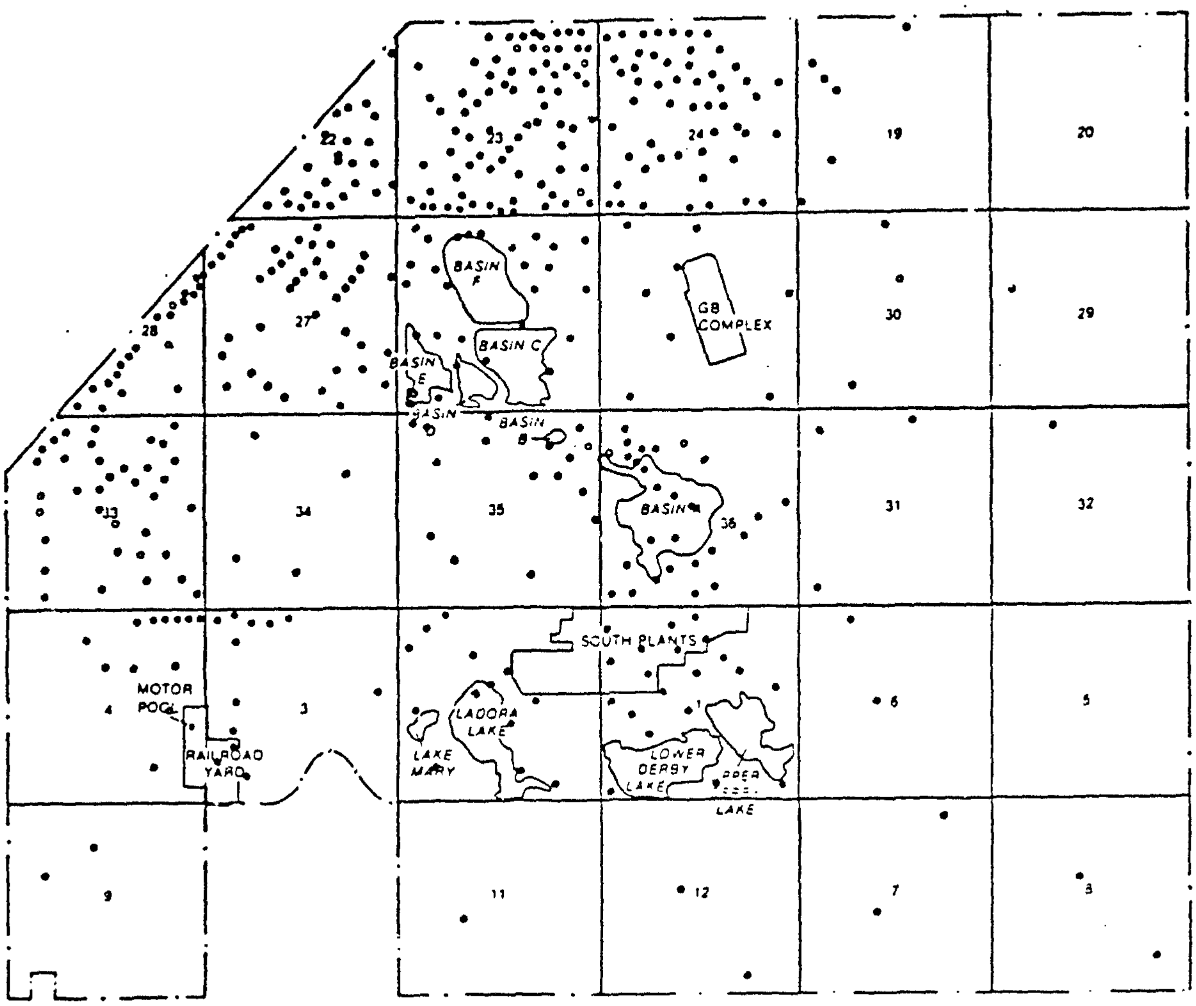
Table 3.1-13. Well Network for Denver Aquifer Water Level Measurements (Page 1 of 2)

Section	Total Wells	Well Numbers
1	30	7, 14, 15, 22, 23, 25, 26, 28, 29, 31, 32, 34, 35, 36, 37, 39, 40, 42, 43, 45, 46, 47, 48, 50, 518, 522, 534, 554, 586, 588
2	29	5, 9, 10, 12, 13, 15, 16, 18, 19, 22, 24, 25, 28, 30, 31, 32, 35, 36, 38, 39, 43, 44, 45, 46, 47, 545, 578, 583, 585
3	4	3, 4, 6, 7
4	3	9, 11, 12
5	3	1, 2, 3
6	2	4, 5
7	2	4, 5
8	2	4, 5
9	2	3, 4
11	1	4
12	2	3, 4
19	7	2, 11, 15, 16, 17, 18, 19
20	0	None
22	7	2, 23, 24, 27, 28, 30, 31
23	15	54, 177, 180, 181, 183, 184, 186, 187, 190, 192, 193, 200, 201, 209, 210

Table 3.1-13. Well Network for Denver Aquifer Water Level Measurements (Continued, Page 2 of 2)

Section	Total Wells	Well Numbers
24	13	86, 109, 120, 124, 125, 136, 159, 167, 168, 171, 172, 174, 175
25	22	4, 7, 9, 10, 12, 13, 14, 16, 17, 19, 20, 21, 23, 24, 25, 26, 29, 31, 34, 37, 39, 40
26	42	27, 28, 43, 51, 52, 53, 54, 55, 56, 57, 58, 60, 61, 64, 66, 67, 69, 72, 75, 77, 79, 80, 82, 84, 86, 89, 90, 92, 94, 96, 97, 123, 128, 129, 130, 134, 135, 140, 141, 142, 146, 147
27	7	49, 54, 55, 57, 59, 60, 61
28	3	25, 26, 29
29	1	3
30	5	5, 7, 8, 10, 11
31	3	7, 8, 11
32	2	2, 3
33	8	26, 27, 28, 29, 31, 32, 34, 35
34	6	3, 4, 6, 7, 9, 10
35	33	8, 9, 12, 13, 15, 16, 17, 24, 27, 28, 32, 33, 35, 36, 38, 39, 41, 50, 51, 54, 55, 56, 59, 60, 62, 63, 67, 68, 70, 71, 72,73, 74
36	21	36, 57, 61, 62, 66, 72, 78, 79, 83, 104, 105, 110, 113, 114, 116, 117, 118, 119, 121, 122, 147

Total: 275



EXPLANATION

- ● Single Alluvial or Upper Denver Well
- o Multiple Alluvial / Upper Denver Wells

N

0 1/2 1 MILE

Figure 3.1-7
WATER LEVEL MEASUREMENT NETWORK
ALLUVIAL WELLS
SOURCE: HARDING LAWSON ASSOCIATES, 1985

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

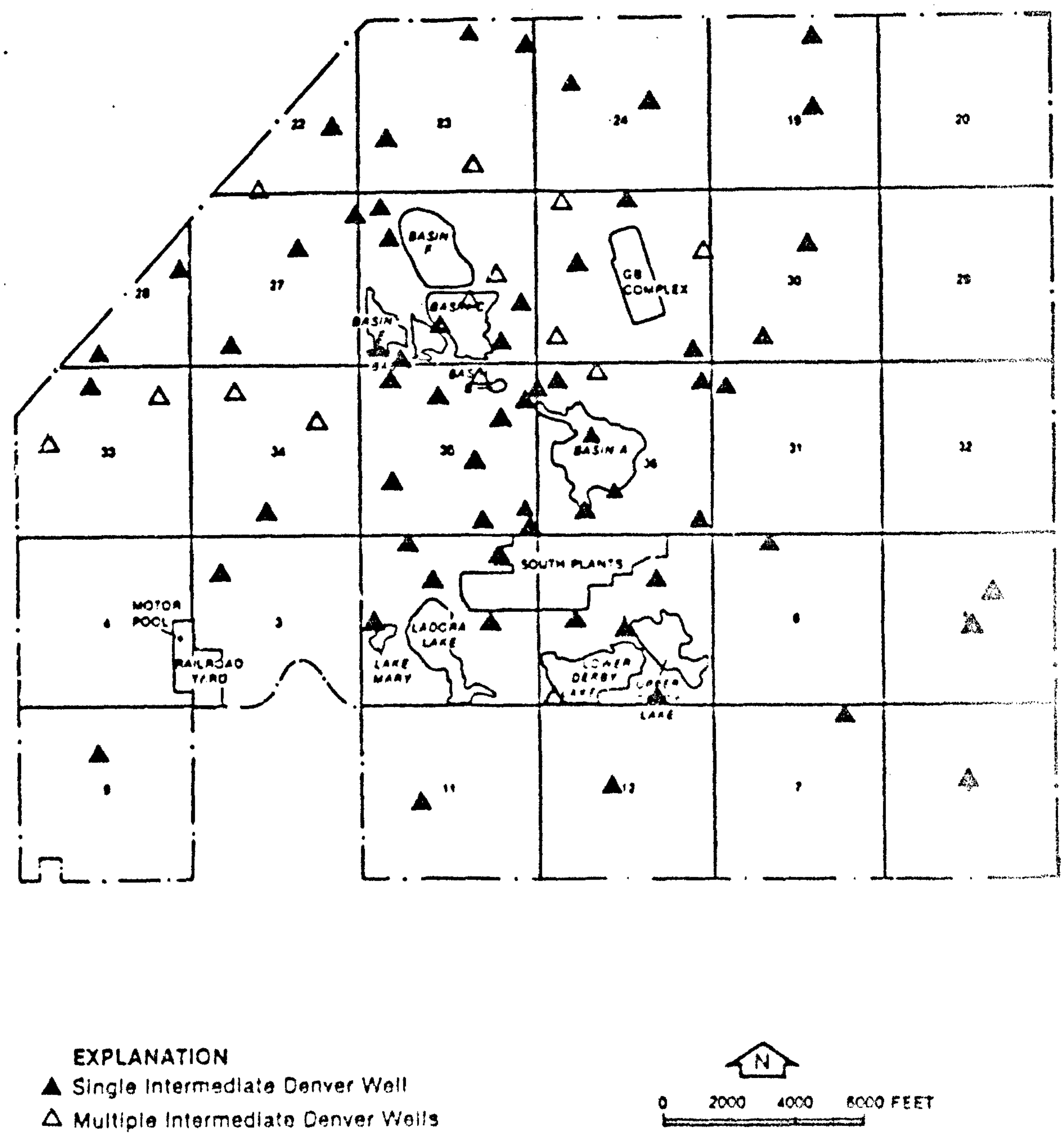
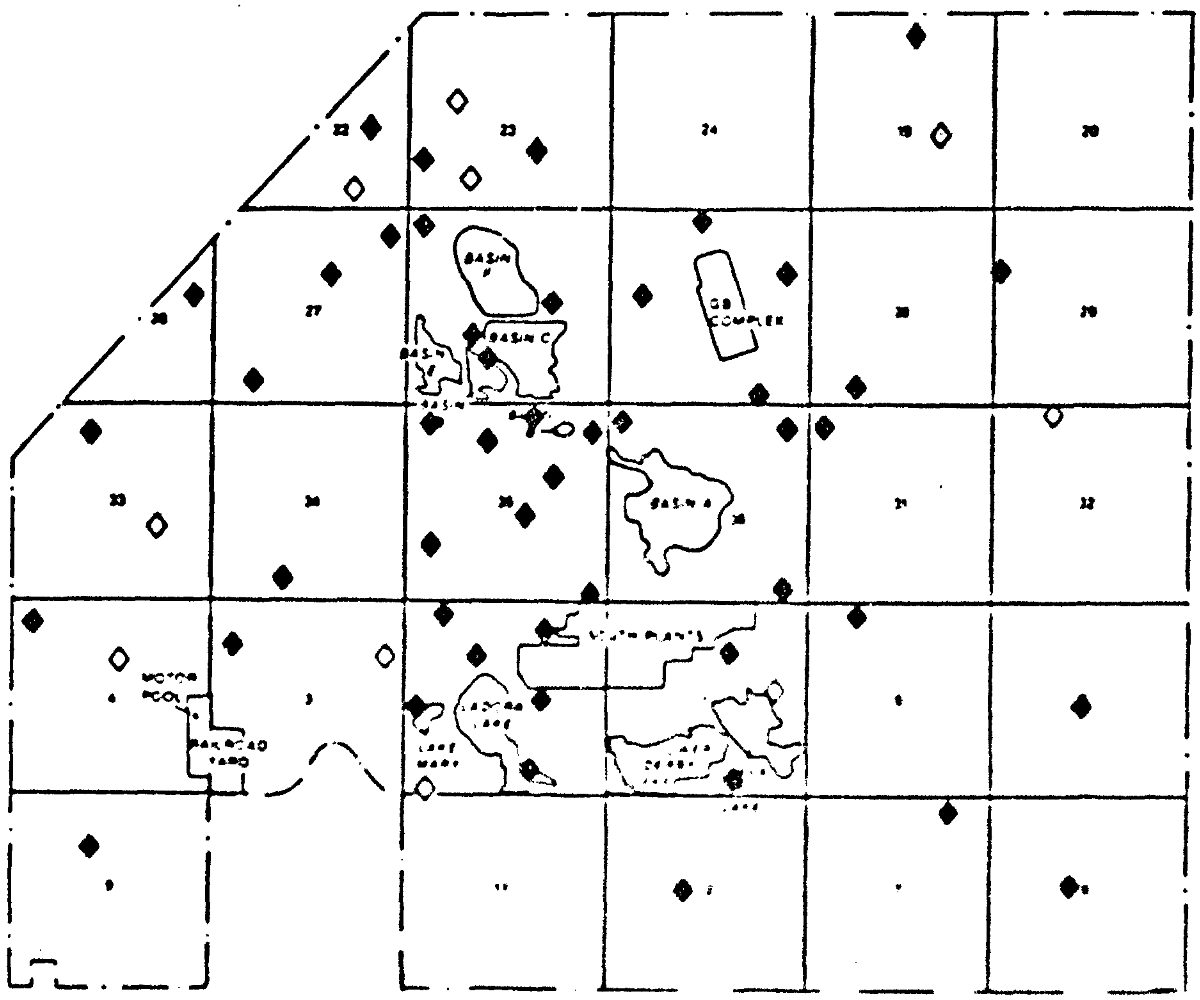


Figure 3.1-8
WATER LEVEL MEASUREMENT NETWORK
INTERMEDIATE DENVER WELLS
(10-50 FEET BELOW CONTACT)

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland



EXPLANATION

◆ Single Lower Denver Well

◇ Multiple Lower Denver Wells

Figure 3.1-9 WATER LEVEL MEASUREMENT NETWORK LOWER DENVER WELLS (>50 FEET BELOW CONTACT)	Prepared for: U.S. Army Program Manager's Office For Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland

evaluation of the boundary control systems. Therefore, monitoring procedures for boundary control wells may be modified based on system conditions and thus will not be performed by Task 4 personnel. However, objectives of the Task 4 program are similar to objectives of the 360° Monitoring and RCRA Ground Water Monitoring Programs. The well selection procedure was designed to give high priority to the inclusion in the Task 4 network of wells sampled under other RMA programs.

Table 3.1-14 lists all ground water monitoring wells designated for sampling under the 360° Monitoring and RCRA Programs. This table also lists which of these wells have been included in or deleted from the Task 4 network. Of the 75 wells sampled under the 360° Monitoring Program, a total of 41 (55%) have been included in the Task 4 program. Wells formerly in the RCRA Monitoring Program were included in the Task 4 network. A total of 394 (80%) of the 490 wells designated for water level measurements under the 360° Program have been included in the Task 4 Program.

As stated previously, 41 of the 75 wells in the 360° Monitoring Program have been included in the Task 4 network. Wells that could not be included in this network generally exhibited inadequate, questionable, or undocumented construction, placing them in the questionable and unacceptable categories. Of the 34 wells not included in the Task 4 network, 18 were of questionable construction, 12 were of unacceptable construction, and 4 were without borehole logs or construction details. Although not all 360° Monitoring Program wells were included in the Task 4 network, adequate coverage in the vicinities of the deleted wells ensures generation of similar water quality data. In many cases well clusters near the unacceptable 360° Monitoring Program wells will provide improved information on water quality and water levels.

Table 3.1-15 presents a comparison of the 360° Monitoring Program water level measurement locations with those envisioned under Task 4. As can be seen from this table, 80 percent of the water level measurements

Table 3.1-14. RMA Onpost 360° and RCRA Ground Water Monitoring Programs

Section	Well Numbers: Included in Task 4 Network	Well Numbers: Not in Task 4 Network
1	14, 21, 27, 30	--
2	20, 23	--
3	1, 5	--
4	10	--
5	1	--
6	2, 3	--
7	1	--
8	2	--
9	2	--
11	2	--
12	2	1
19	--	1, 4
22	--	1, 3, 4, 5, 6, 8, 17
23	7, 29, 49*, 95*, 108*, 142*	2, 3, 6, 72
24	1	3, 6, 57
25	11	--
26	15*, 17**, 20**, 41*, 73*, 85*, 127*, 133	5, 6, 8, 48
27	3, 16*, 40	2, 11, 24, 35
28	23, 27	10
30	9	1
31	5	1
33	2, 18, 25, 30	1
34	5, 8	--
35	5, 12, 61	1,2
36	1, 116, 118, 121	93

* = RCRA Program

** = Both Programs

Table 3.1-15. Comparison of Current RMA Onpost 360° Program Water Level Measurements with the Task 4 Program

Section	360°	Task 4	Rejects	No Logs	Duplicates
1	22	21	—	1	—
2	20	15	—	3	2
3	8	8	—	—	—
4	9	6	—	3	—
5	3	3	—	—	—
6	4	4	—	—	—
7	4	4	—	—	—
8	4	4	—	—	—
9	4	3	—	1	—
11	3	3	—	—	—
12	4	4	—	—	—
19	15	15	—	—	—
20	0	1	—	—	—
22	20	16	2	1	1
23	66	50	8	8	—
24	47	32	12	3	—
25	16	13	2	0	1
26	56	45	3	5	3
27	39	28	11	—	—
28	12	11	1	—	—
29	2	2	—	—	—
30	11	9	2	—	—
31	10	8	2	—	—
32	3	3	—	—	—
33	22	14	4	4	—
34	11	9	1	1	—
35	43	36	6	1	—
36	32	27	2	3	—
TOTALS	490	394	56	33	7

collected under the 360° Monitoring Program will be collected under Task 4. The remaining 20 percent represent wells that were rejected from the Task 4 program due to well construction factors, wells for which boring/completion logs could not be located, and wells which were considered to provide duplicate information to that being obtained from other wells.

3.1.3 THIRD QUARTER (FY86) SAMPLING PROGRAM

Based on the ISP results, 186 wells have been proposed for continued quarterly sampling. The primary criteria for selection were the locations of the wells with respect to contaminant plumes and the occurrence of discrepancies between historical and ISP chemical data. Secondary criteria for well selection include preference of vertical clusters of wells, adequate documentation of construction, wells that did not dewater, and wells which could be pumped. Wells that could not be sampled during the ISP were automatically rejected.

3.1.3.1 Construction Re-Evaluation

Construction evaluations were re-examined for all of the wells included in the ISP. Additional information on well conditions was provided by field observations. These observations are summarized in Table 3.1-16, which includes physical condition, (constricted, destroyed, etc.) and sampling technique (pump vs bail). This information was used to reject wells which could not be sampled and to select wells with preferred characteristics.

3.1.3.2 Definition of Contaminant Plumes

Three aspects of contaminant plume geometry will be monitored by sampling wells selected for the third quarter. Central areas of plumes will be sampled to document changes in high level contamination. Wells which define plume boundaries will be sampled to monitor any changes in the lateral and vertical extent of ground water contamination. Background wells will be sampled to verify that ground water in these areas remains uncontaminated.

3.1.3.3 Resolution of Data Discrepancies

Discrepancies between the historical chemical data and ISP results have been identified. Discrepancies between Task 4 and historical data were

Table 3.1-16. Screening Program Well Summary (Page 1 of 8)

Well Number	Ranking (1-4)	Pump/Bailer	Sample Depth	Comments
01008	2	36" Bailer	22'	
01012	2	22" Bailer	14.5'	
01014	2	28" Bailer	20'	
01017	2	22" Bailer	13.6'	
01019	2	28" Bailer	25'	
01020	2	22" Bailer	16.1'	
01021	4	28" Bailer	18.3'	
01022	4	48" Bailer	26'	
01023	4	28" Bailer	56.2'	
01024	4	28" Bailer	9'	
01025	4	28" Bailer	62'	
01026	4	*	*	Well Destroyed
01027	4	28" Bailer	15'	
01028	4	Pumped	72'	Dewatered at 2.5 Vol
01029	4	Pumped	115'	Dewatered at 1.5 Vol
01030	3	28" Bailer	15'	
01031	4	Pumped	32.7'	
01032	4	Pumped	25'	
01033	3	Bailed	10'	
01034	4	Bailed	90'	
01035	4	Pumped	10'	Casing broken 2" from ground
02008	2	48" Bailer	117'	
02009	4	48" Bailer	47'	
02010	4	24" Bailer	46'	Only one that fits
02011	4	24" Bailer	45'	
02012	4	48" Bailer	56'	
02013	4	*	*	Constriction at 27'-30'
02017	3	*	*	Well dry
02018	4	28" Bailer	60'	
02019	4	28" Bailer	60'	
02020	4	28" Bailer	11'	
02021	4	*	*	Constricted; 36" and 25" bailers won't fit
02022	4	28" Bailer	45'	
02023	4	22" Bailer	15'	
02024	4	28" Bailer	31.8'	
02025	4	28" Bailer	54'	48" and 36" bailers got stuck
02030	4	36" Bailer	90'	
02031	4	48" Bailer	68'	
02034	3	22" Bailer	15'	
02035	3	Pumped	41.2'	Dewatered at 1.6 Vol
02036	3	48" Bailer	28'	
02037	2	28" Bailer	16"	
02038	3	Pumped	17'	
02039	3	Pumped	38'	

Table 3.1-16. Screening Program Well Summary (Continued, Page 2 of 8)

Well Number	Ranking (1-4)	Pump/Bailer	Sample Depth	Comments
03001	2	Pumped	96'	
03002	3	Bailed	70'	
03003	4	48' Bailed	117'	
03004	4	20" Bailed	179'	
03005	4	Pumped	24.7'	
03006	4	36" Bailer	128'	Dewatered at 1.3 Vol
03007	4	Pumped	196'	Dewatered at 1 Vol
03008	†	Bailed	65'	Dewatered at 3 Vol
03009	†	Pump Rig	77'	
03010	†	Bailed	72'	
03523	1	Pumped	70'	
04001	†	Pumped	67'	
04004	†	Pumped	53'	
04007	4	Pumped	54'	
04008	4	22" Bailer	60'	
04009	4	Bailed	154'	
04010	4	36" Bailer	63.5'	
04011	4	36" Bailer	158'	
04012	4	*	*	Well casing constricted
04013	†	Bailed	72'	
04014	†	Bailed	73'	
04019	†	Pumped	75'	
04020	†	Pumped	66'	
04021	†	36" Bailer	73'	
04022	†	36" Bailer	73'	
04023	†	36" Bailer	73'	
04024	†	Pumped	73'	
04025	†	Pumped	74'	
04026	†	Pumped	57.5'	
04027	†	Pumped	67'	
04028	†	Pumped	67.5'	
04029	†	Pumped	67.5'	
04030	†	36" Bailer	68'	
04031	†	Bailed	68.5'	
04032	†	Pumped	80'	
04033	†	Pumped	75'	
04524	1	Bailed	64'	
05001	1	Pump Rig	34'	Dewatered at 1 Vol
05002	4	Bailed	63'	Dewatered at 1 Vol
05003	4	Bailed	77'	Dewatered at 1 Vol
06002	2	Pump Rig	12'	
06003	4	Bailed 28'	17'	
06004	4	Bailed	65'	
06005	4	36" Bailer	19'	
07001	2		25'	Dewatered at 1 Vol

Table 3.1-16. Screening Program Well Summary (Continued, Page 3 of 8)

Well Number	Ranking (1-4)	Pump/Bailer	Sample Depth	Comments
07003	3	*	*	Well Dry
07004	4	Bailed	65'	Dewatered at 2 Vol
07005	4	Bailed	139'	Dewatered at 1 Vol
08002	2	Pumped Rig	21'	
08003	4	28" Bailer	9'	
08004	4	Pumped	38'	
08005	4	48" Bailer	50'	
09001	†	Pumped	58'	Dewatered at 1 Vol
09002	4	Pumped	70'	
09003	4	28" Bailer	73'	
09004	4	28" Bailer	170'	Well bailed until end of day-3 Vol
09005	4	Pumped	65'	
09006	4	Pumped	53'	
09007	4	Pumped	61'	
11002	4	Pumped	19'	
11003	3	28" Bailer	55.8'	
11004	4	46" Bailer	48.4'	
12002	4	22" Bailer	20'	
12003	4	Pumped	20'	
12004	4	Bailed	125'	Dewatered at 3 Vol
19014	4	*	*	Well Dry
19015	4	36" Bailer	43'	
19016	4	28" Bailer	133'	Dewatered at 1 Vol
19017	4	28" Bailer	30'	
19018	4	28" Bailer	56.8'	Dewatered at 1 Vol
19019	4	28" Bailer	116'	
22020	3	Pumped	33'	Dewatered at 1 Vol
22021	3	22" Bailer	33.3'	
22022	3	28" Bailer	34'	
22023	4	Bailed	35'	
22024	4	Pumped	106.7'	Dewatered at 1 Vol
22025	3	*	*	Well Dry
22027	4	28" Bailer	77'	
22028	4	36" & 28" Bailer	115'	
22029	3	*	*	Well Dry
22030	4	Pumped	90'	
22031	4	Pumped	60	
22049	4	*	*	Well Dry
22059	3	28" Bailer	51'	
22060	4	28" Bailer	39'	Dewatered at 3 Vol
23007	3	Bailed	42'	
23029	2	Bailed	22'	
23039	2	*	*	Well Dry
23049	1	*	*	Well Dry
23095	1	Bailed	44'	
23108	1	Bailed	40'	
23142	2	Pumped	51.4'	Well Wizard
23166	3	22" Bailer	16'	Dewatered at 1 Vol

Table 3.1-16. Screening Program Well Summary (Continued, Page 4 of 8)

Well Number	Ranking (1-4)	Pump/Bailer	Sample Depth	Comments
23176	3	Pumped Rig	40'	
23177	4	Pumped	18'	
23178	3	28" Bailer	14.5'	
23179	4	Bailed	51.5'	Dewatered at 2 Vol
23180	4	Bailed	72'	Dewatered at 1 Vol
23181	4	Bailed	102'	Dewatered at 2 Vol
23182	4	Bailed	35'	
23183	4	Bailed	39'	
23184	4	28" Bailer	122'	
23185	4	Bailed	46'	
23186	4	Pumped	57'	
23187	4	48" Bailer	103'	
23188	4	22" Bailer	26.5'	
23189	4	Bailed	45'	
23190	4	22" & 28" Bailer	87.5'	
23191	4	28" Bailer	55'	
23192	4	Pumped	189'	Dewatered at 1 Vol
23193	4	Pumped	175'	Dewatered at 1.3 Vol
24001	3	Bailed	32'	
24150	3	Bailed	10'	
24158	3	Bailed	9'	
24159	4	24" Bailer	13'	
24170	3	*	*	Casing broken off below ground
24178	3	Bailed	11'	
24179	3	Pumped	8.6'	
24184	3	Bailed	9'	
24185	3	Bailed	9'	
24188	3	*	*	Well destroyed
25008	4	Bailed	60'	
25009	4	28" Bailer	66'	
25010	4	28" Bailer/Pump	139'	Dewatered at 1 Vol
25011	4	28" Bailer	13'	
25012	4	28" Bailer	61.5'	Dewatered at 1.75 Vol
25013	4	28" Bailer	92.0'	Dewatered at 1 Vol
25014	4	36" Bailer	76'	
25015	4	22" Bailer	40'	
25016	4	Bailed	67'	Dewatered at 1 Vol
25017	4	28" Bailer	68'	Dewatered at 2 Vol
25018	4	*	*	Well constricted
25019	4	36" Bailer	85'	Dewatered at 1 Vol
25020	4	36" Bailer	42.1'	
25022	3	28" Bailer	57.8'	Dewatered at 1 Vol
25023	3	28" Bailer	57.7'	
25024	3	Bailed	94	
25038	3	28" Bailer	27'	
25039	3	Bailed	30.5'	

Table 3.1-16. Screening Program Well Summary (Continued, Page 5 of 8)

Well Number	Ranking (1-4)	Pump/Bailer	Sample Depth	Comments
25040	3	28" Bailer	84.2'	Dewatered at 2.5 Vol
26011	2	Bailed	47'	
26015	1	Bailed	54'	
26017	1	Bailed	49'	
26020	1	Bailed	49.5'	Dewatered while sampling
26041	2	Bailed	49.2	
26065	2	*	*	Well Dry
26066	2	48" Bailer	41'	
26067	2	Pumped	52'	
26070	2	*	*	Well Dry
26071	2	Pumped	45.6'	
26072	2	Pumped	53.2'	
26073	2	Bailed	51'	
26074	2	Bailed	58'	
26075	2	Pumped	60'	
26076	2	*	*	Well Dry
26083	2	48" Bailer	30'	Dewatered at 2 Vol
26084	2	Pumped	86'	Dewatered at 2 Vol
26085	2	36" Bailer	34'	
26086	2	Pumped	41'	
26091	1	36" Bailer	32'	
26092	2	Pumped	30'	
26093	2	Bailed	28'	Dewatered at 3 Vol
26094	2	Pumped	40'	
26127	2	28" Bailer	45'	
26128	2	Pumped	43'	
26129	2	Pumped	55'	
26132	2	*	*	Well stickup gone, well could not be located
26133	2	Bailed	44.2'	
26140	3	48" Bailer	63'	
26141	3	36" Bailer	72.5'	
26142	3	Pumped	149'	Dewatered at 1.9 Vol
26145	4	Bailed	*	Dewatered, never recharged
26146	4	*	*	Well constricted
26147	4	Pumped	52'	
27003	2	Bailed	51'	
27016	1	Bailed	25'	
27040	2	22" Bailer	41'	Dewatered at 1.5 Vol
27053	4	28" Bailer	57'	
27054	4	Pumped	105'	Dewatered at 1 Vol
27055	4	Pumped	137'	Dewatered at 1 Vol
27056	4	22" Bailer	47'	
27057	4	22" Bailer	66.7'	Dewatered at 2 Vol
27058	4	28" Bailer	101'	Dewatered at 1 Vol
27059	4	*	*	Well constricted
27060	4	*	*	Well obstructed
27061	4	*	*	Well obstructed

Table 3.1-16. Screening Program Well Summary (Continued, Page 6 of 8)

Well Number	Ranking (1-4)	Pump/Bailer	Sample Depth	Comments
27062	4	28" Bailer	45'	
27074	4	Bailed	44.2'	
27075	2	22" Bailer	55.6'	
27076	4	28" Bailer	58'	
27077	4	28" Bailer	55.6'	
27078	4	28" Bailer	62'	
28023	2	28" Bailer	38'	
28025	4	28" Bailer	95'	Dewatered at 1 Vol
28026	3	Pump & 28" Bailer	114'	Dewatered at 1 Vol
28027	2	28" Bailer	43'	
28028	4	22" Bailer	41.7'	
28029	4	*	*	Well Obstructed
29002	4	22" Bailer	40'	
29003	4	28" Bailer	113.2'	
30003	4	*	*	Well Dry
30004	4	Bailed	47'	Dewatered at 3 Vol
30005	4	Pumped	50'	
30009	4	28" Bailer	12'	
30010	4	Pumped	18'	
30011	4	Pumped	137'	Dewatered at 1 Vol
31005	4	Pumped	30'	
31006	4	Pumped	28'	
31007	4	Pumped	80'	Dewatered at 1 Vol
31008	4	48" Bailer	33'	
32001	1	36" & 28" Bailer	31'	
32002	4	Pumped	101.9	
32003	4	Pumped	76	
33002	2	Pumped	50'	
33015	†	pumped	69.5	
33016	2	Bailed	68'	Nearly Dewatered
33017	†	Pumped	60.5'	
33018	2	24" Bailer	73'	Dewatered at 3 Vol
33019	2	28" Bailer	69'	
33020	2	Bailed	69'	
33021	2	24" Bailer	70'	
33022	2	24" Bailer	70'	
33023	2	24" Bailer	65'	
33024	2	Bailed	67.6'	
33025	2	Bailed	63'	Dewatered at 4 Vol
33026	4	Bailed	60'	
33027	4	Pumped	58.3'	
33028	4	*	*	Well Dry
33029	4	*	*	Bailer would not fit down hole
33030	4	24" Bailer	64'	
33031	4	*	*	Well constricted

Table 3.1-16. Screening Program Well Summary (Continued, Page 7 of 8)

Well Number	Ranking (1-4)	Pump/Bailer	Sample Depth	Comments
33032	4	36" Bailer	201'	Dewatered at 1 Vol
33033	4	24" Bailer	51'	
33034	4	28" Bailer	54'	
33035	4	36" Bailer	109'	Dewatered at 1 Vol
33046	†	Bailed	62'	
33047	†	Bailed	73'	Dewatered at 3+ Vol
33060	4	36" Bailer	63.5'	
33061	4	28" Bailer	82'	
33062	4	*	*	Well Dry
33063	3	28" Bailer	72'	
33514	2	Bailed	59'	Dewatered at 2 Vol
34002	4	Bailed	80'	
34003	4	28" Bailer	83.5'	
34004	4	*	*	Well Constricted
34005	4	Bailed	74'	
34006	4	Bailed	70'	
34007	4	Bailed	134'	Dewatered at 1.5 Vol
34008	4	22" Bailer	65'	
34009	4	28" Bailer	100'	Dewatered at 2 Vol
34010	4	22" Bailer	75'	
35005	2	Bailed	33'	
35012	2	Pumped	26.5'	Dewatered at 4 Vol
35013	2	28" Bailer	20'	
35016	2	28" Bailer	26'	
35017	2	Pumped	70'	Dewatered at 2 Vol
35034	2	Bailed	16'	Dewatered at 1 Vol
35035	3	*	*	Well destroyed
35036	3	Bailed	32'	
35037	2	22" Bailer	37.4	
35038	3	Pumped	41.5	
35039	3	Pumped	63.1'	
35052	4	28" Bailer	15'	
35053	4	22" Bailer	58'	Dewatered at 1 Vol
35054	4	Bailed	80'	Dewatered at 1 Vol
35055	4	*	*	Well obstructed
35056	4	Pumped	78'	
35058	4	28" Bailer	30.8'	
35059	4	Pumped	60'	Dewatered at 2 Vol
35060	4	*	*	Well Obstructed
35061	4	28" Bailer	28'	
35062	4	22" Bailer	80'	Dewatered at 1.5 Vol
35063	4	36" Bailer	55'	
36065	4	22" Bailer	21.6'	
35066	4	28" Bailer	20'	

Table 3.1-16. Screening Program Well Summary (Continued, Page 8 of 8)

Well Number	Ranking (1-4)	Pump/Bailer	Sample Depth	Comments
35067	4	36" Bailer	85'	Dewatered at 1+ Vol
35068	4	Pumped	47.9	
35069	4	28" Bailer	20'	
35070	4	Pumped	75'	
35071	3	Pumped	26'	
35072	3	*	*	Well Obstructed
36001	2	Bailed	17'	
36048	†	36" Bailer	22'	Dewatered at 1 Vol
36065	2	36" Bailer	20'	Dewatered at 1.5 Vol
36066	2	Pumped	60'	Dewatered at 2 Vol
36069	2	Bailed	21'	
36075	2	28" Bailer	13.5'	
36076	2	22" Bailer	22'	
36082	2	36" Bailer	9'	
36083	2	Pumped	28'	
36084	2	36" Bailer	11.8'	
36090	2	Bailed	28'	
36091	2	*	*	Well Dry
36109	2	48" Bailer	17'	
36110	2	36" Bailer	43'	
36112	4	28" Bailer	35'	
36113	3	36" Bailer	83'	Dewatered at 1+ Vol
36114	3	36" Bailer	65'	
36116	4	*	*	Well Dry
36117	3	28" Bailer	82'	Dewatered at 1 Vol
36118	4	Pumped	75'	Dewatered at 1 Vol
36119	3	36" Bailer	86'	Dewatered at 1 Vol
36121	4	28" Bailer	43'	
36122	3	36" Bailer	64'	
36136	3	36" Bailer	18'	
36137	3	28" Bailer	19'	
36138	3	48" Bailer	21'	
36139	3	48" Bailer	20'	
36140	3	36" Bailer	18'	
36141	3	46" Bailer	38.7'	
36142	3	36" Bailer	21'	

* Unable to sample
† No information available for ranking

evaluated on a qualitative basis. Results were compared on a well by well basis to identify locations where compounds were detected in one period but not the other. Those wells displaying significant discrepancies will be included in the third quarter sampling program to verify results. Once these problems are resolved, wells may be dropped from subsequent sampling programs if they fail to provide additional information.

3.1.3.4 Other Programs

Twelve wells sampled by the ongoing RCRA regulatory program were automatically included in the third quarter sampling program.

3.1.3.5 Proposed Monitoring Network

The selection of wells from the ISP for inclusion in the third quarter program was based on the evaluations discussed above. The locations of proposed alluvial, intermediate Denver, and lower Denver wells are shown in Plates 1, 2, and 3, respectively. A summary of characteristics considered in selecting each well are listed in Table 3.1-17.

Wells deleted from the sampling program fell into three categories:

- Wells that could not be sampled;
- Wells in close proximity to chosen wells with preferred characteristics; or
- Wells located such that samples would not yield significant additional information.

The wells rejected and the reason for deletion from the program are listed in Table 3.1-18. Details of program design and data reduction/compilation are presented in initial screening effort report (ESE, 1986).

3.1.4 LONG TERM SAMPLING PROGRAM

Based on the combined screening programs and third quarter results, the wells selected above will be reevaluated in a similar manner. Wells for which discrepancies in data have been resolved may be deleted from the program. Recommendations for additional wells will be provided. A final network for long term monitoring will be established at this time.

Table 3.1-17. Wells Selected for Inclusion in the Third Quarter Sampling Program (Page 1 of 7)

Region Well Number	Aquifer*	Chemical Discrepancies	Plume Geometry Central	Plume Geometry Boundary	Plume Geometry Background	Cluster	Documentation	Sampling Method	RCRA**	Comments
South										
07001	A	x			x		2			
07004	I				x	x	4	Bail		
07005	L				x	x	4	Bail		
08003	A	x			x	x	4	Bail		Pesticides only
11002	A	x			x	x	4	Pump		
11004	I				x	x	4	Bail		
12002	A				x	x	4	Bail		
12003	I				x	x	4	Pump		
12004	L				x	x	4	Bail		
East										
06002	A	x			x		2	Pump		
06003	A				x	x	4	Bail		
06004	I				x	x	4	Bail		
06005	L	x			x	x	4	Bail		
19015	I	x			x	x	4	Bail		
19016	L	x			x	x	4	Bail		Confirm benzene
19019	L	x			x		4	Bail		Confirm benzene
30005	I	x			x	x	4	Pump		Pesticides only
30009	A				x	x	4	Bail		Pesticides only
30010	I				x	x	4	Pump		
30011	L				x	x	4	Pump		
31006	A	x			x	x	4	Pump		
31008	L				x	x	4	Bail		
320[illegible]	A	x			x		1	Bail		Pesticides only

Table 3.1-17. Wells Selected for Inclusion in the Third Quarter Sampling Program (Continued, Page 2 of 7)

Region Well Number	Aquifer*	Chemical Discrepancies	Plume Geometry Central	Plume Geometry Boundary	Plume Geometry Background	Cluster	Documentation	Sampling Method	RCRA**	Comments
West										
03002	A			x		x	3	Bail		
03003	I	x		x		x	4	Bail		
03004	L			x		x	4	Bail		
03008	A	x		x				Bail		
03523	A		x				1	Pump		
04007	A			x		x	4	Pump		
04009	L	x		x		x	4	Bail		
04010	A			x		x	4	Bail		
04011	L			x		x	4	Bail		
04014	A			x		x	4	Bail		
04016	D			x						
04021	A			x				Bail		
04024	A			x						
04027	A		x			x		Pump		
04029	A		x			x		Pump		
04030	A		x			x		Bail		
04031	A		x			x		Bail		
04032	A		x			x		Pump		
04033	D		x			x		Pump		
04524	A			x			1	Bail		
09001	A			x				Pump		
09002	A				x	x	4	Pump		
09003	I	x			x	x	4	Bail		
09005	A			x				Pump		
28027	A	x			x		2	Bail		
33002	A	x		x			2	Pump		
33016	A			x			2	Bail		
33023	A	x		x			2	Bail		
33025	A	x		x		x	2	Bail		

Table 3.1-17. Wells Selected for Inclusion in the Third Quarter Sampling Program (Continued, Page 3 of 7)

Region Well Number	Aquifer*	Chemical Discrepancies	Plume Geometry Central	Plume Geometry Boundary	Plume Geometry Background	Cluster	Documentation	Sampling Method	RCRA**	Comments
West										
33026	I	x		x		x	4	Bail		
33027	L	x		x		x	4	Pump		
33030	A	x		x		x	4	Bail		
33032	L			x		x	4	Bail		Verify pesticides-
33033	A	x		x		x	4	Bail		Verify pesticides,
33034	I	x		x		x	4	Bail		Verify pesticides
33060	A			x		x	4	Bail		
33061	A			x		x	4	Bail		
34515	A									Not sampled in Screening Quarter
Central										
01012	A	x	x				2	Bail		
01014	I	x		x			2	Bail		
01020	A	x	x				2	Bail		GC/MS-purgeables
01021	A	x			x	x	4	Bail		
01022	I	x			x	x	4	Bail		Possible GC/MS con
01023	L				x	x	4	Bail		
01024	A				x	x	4	Bail		
01025	I				x	x	4	Bail		
G1030	A	x	x			x	3	Bail		
01031	I			x		x	4	Pump		
01032	L			x		x	4	Pump		
02008	A	x		x		x	2	Bail		
02009	I	x		x		x	4	Bail		
02010	L	x		x		x	4	Bail		
02011	A	x			x	x	4	Bail		
02012	L	x			x	x	4	Bail		
02019	L	x		x		x	4	Bail		Confirm pesticides

Table 3.1-17. Wells Selected for Inclusion in the Third Quarter Sampling Program (Continued, Page 4 of 7)

Region Well Number	Aquifer*	Chemical Discrepancies	Plume Geometry Central	Boundary	Background	Cluster	Documentation	Sampling Method	RCRA**	Comments
Central										
02020	A	x			x		4	Bail		
02030	I	x		x		x	4	Bail		
02031	L	x		x		x	4	Bail		
02034	A	x		x		x	3	Bail		
02035	I	x		x		x	3	Pump		
02036	L	x		x		x	3	Bail		
02037	A	x		x		x	2	Bail		
02038	I	x		x		x	3	Pump		
02039	L	x		x		x	3	Pump		
03005	A	x		x			4	Pump		
22021	A	x	x			x	3	Bail		
22024	I	x	x			x	4	Pump		
22059	D		x				3	Bail		
22060	A		x				4	Bail		
23049	A		x				1		x	Well dry
23095	A		x						x	
23108	A		x						x	
23125	I		x							Not sampled in Scre Quarter
23142	A						2	Pump	xo	
23166	A	x	x				3	Bail		
23177	I	x		x		x	4	Pump		
23179	A			x		x	4	Bail		
23180	I	x	x				4	Bail		
23182	A			x		x	4	Bail		
23183	L			x		x	4	Bail		
23185	A		x			x	4	Bail	o	
23186	I		x			x	4	Pump	o	
23187	L	x	x			x	4	Bail	o	
23188	A	x		x			4	Bail		
23190	L	x		x		x	4	Bail		
23191	A	x		x		x	4	Bail	o	
23192	L			x		x	4	Pump	o	

Table 3.1-17. Wells Selected for Inclusion in the Third Quarter Sampling Program (Continued, Page 5 of 7)

Region Well Number	Aquifer*	Chemical Discrepancies	Plume Geometry Central	Plume Geometry Boundary	Plume Geometry Background	Cluster	Documentation	Sampling Method	RCRA**	Comments
Central										
24136	I									Not sampled in Scre Quarter
24150	A				x		3	Bail		
24158	A				x	x	3	Bail		
24159	I				x	x	4	Bail		
24178	A			x			3	Bail		
24185	A			x			3	Bail		
25008	A			x		x	4	Bail		
25009	I			x		x	4	Bail		
25010	L			x		x	4	Pump		
25011	A	x			x	x	4	Bail		
25012	I	x			x	x	4	Bail		
25013	L	x			x	x	4	Bail		
25015	A			x		x	4	Bail		
25016	I			x		x	4	Bail		
25022	A			x		x	3	Bail		
25023	I	x		x		x	3	Bail		
26011	A		x				2	Bail	o	
26015	A		x						x	
26017	A		x						x	
26020	A		x						x	
26066	I	x	x				2	Bail		
26041	D	x	x				2	Bail	xo	
26073	A	x	x				2	Bail	xo	
26076	A		x			x	2	Bail	x	
26083	A	x	x			x	2	Bail	o	
26084	I		x			x	2	Pump	o	
26085	A	x	x			x	2	Bail	xo	
26086	L	x	x			x	2	Pump		
26127	A	x	x			x	2	Bail	xo	
26128	I		x			x	2	PUmp		
26133	A	x	x				2	Bail		
26140	I	x	x			x	3	Bail		
26142	L	x	x			x	3	Pump		
26147	L		x				4	Pump		

Table 3.1-17. Wells Selected for Inclusion in the Third Quarter Sampling Program (Continued, Page 6 of 7)

Region Well Number	Aquifer*	Chemical Discrepancies	Plume Geometry Central	Plume Geometry Boundary	Plume Geometry Background	Cluster	Documentation	Sampling Method	RCRA**	Comments
Central										
27005	A									Not sampled in Scre Quarter
27032	A									Not sampled in Scre Quarter
27040	A	x	x				2	Bail		
27053	A	x		x		x	4	Bail		
27054	I			x		x	4	Pump		
27055	L			x		x	4	Pump		
27056	A		x			x	4	Bail		
27057	I	x	x			x	4	Bail		
27058	L		x			x	4	Bail		
27062	A	x		x			4	Bail		
28023	A			x		x	2	Bail		
28025	I	x		x		x	4	Bail		
28026	L	x		x		x	3	Pump		
34002	A		x				4	Bail		
34008	A	x		x		x	4	Bail		
34009	I	x		x		x	4	Bail		
35012	I	x	x				2	Pump		
35013	I	x	x				2	Bail		
35034	A		x				2	Bail		
35037	A	x		x		x	2	Bail		
35038	I	x		x		x	3	Pump		
35039	L	x		x		x	3	Pump		
35052	A	x		x			4	Bail		
35058	A			x		x	4	Bail		
35059	I			x		x	4	Pump		
35061	A	x		x		x	4	Bail		
35062	I			x		x	4	Bail		
35063	L			x		x	4	Bail		
35065	A	x	x			x	4	Bail		

Table 3.1-17. Wells Selected for Inclusion in the Third Quarter Sampling Program (Continued, Page 7 of 7)

Region Well Number	Aquifer*	Chemical Discrepancies	Plume Geometry Central	Plume Geometry Boundary	Plume Geometry Background	Cluster	Documentation	Sampling Method	RCRA**	Comments
Central										
35067	I	x	x			x	4	Bail		
35068	L	x	x			x	4	Pump		
36001	A	x	x				2	Bail		
36065	A	x		x		x	2	Bail		
36066	I			x		x	2	Pump		
36075	A	x	x				2	Bail		
36076	A	x	x				2	Bail		
36082	A	x	x			x	2	Bail		
36083	I	x	x			x	2	Pump		
36110	I			x			2	Bail		
36112	A	x		x		x	4	Bail		
36113	I	x		x		x	3	Bail		
36114	L			x		x	3	Bail		
36121	I	x			x		4	Bail		
36139	A		x				3	Bail		

* x = A = Alluvial Aquifer
I = Intermediate Denver
L = Lower Denver
D = Denver, uncertain

** x = Current RCRA Monitoring Well
o = Proposed RCRA Monitoring Well

Table 3.1-18. Wells Deleted From Sampling Program (Page 1 of 4)

Region / Well Number	Unable to Sample	Proximity	No Information
South			
07003	x		
08002		x	
08004			x
08005			x
11003		x	
East			
05001			x
05002			x
05003			x
19014	x		
19017			x
19018		x	
29002			x
29003			x
30003	x		
30004		x	
31005		x	
31007		x	
32002			x
32003			x
West			
03001		x	
03009		x	
03010		x	
04001		x	
04002	x		
04004		x	
04008		x	
04012	x		
04013		x	
04015		x	
04019			x
04020			x
04022		x	
04023		x	
04025		x	
04026		x	
04028		x	
09004		x	
09006		x	
09007		x	
28028		x	
28029	x		
33015		x	

Table 3.1-18. Wells Deleted From Sampling Program (Page 2 of 4)

Region Well Number	Unable to Sample	Proximity	No Information
West			
33017		x	
33018		x	
33019		x	
33020		x	
33021		x	
33022		x	
33024		x	
33028	x		
33029	x		
33031	x		
33035		x	
33046		x	
33047		x	
33062	x		
33063		x	
33514		x	
Central			
01008		x	
01017		x	
01019			x
01026	x		
01027		x	
01028			x
01029			x
01033		x	
01034			x
01035			x
02013	x		
02017	x		
02018		x	
02021	x		
02022		x	
02023		x	
02024		x	
02025		x	
03006		x	
03007		x	
22020		x	
22022		x	
22023		x	
22025	x		
22027		x	
22028		x	
22029	x		
22030		x	

Table 3.1-18. Wells Deleted From Sampling Program (Page 3 of 4)

Region Well Number	Unable to Sample	Proximity	No Information
Central			
22031		x	
22049		x	
23007		x	
23029		x	
23039	x		
23176		x	
23178		x	
23181		x	
23184		x	
23189		x	
23193		x	
24001		x	
24170	x		
24179		x	
24184		x	
24188	x		
25014		x	
25017		x	
25018	x		
25019			x
25020			x
25024		x	
25038			x
25039			x
25040			x
25065	x		
26067		x	
26070	x		
26071		x	
26072		x	
26074		x	
26075		x	
26091		x	
26092		x	
26093		x	
26094		x	
26129		x	
26132	x		
26141		x	
26145		x	
26146	x		
27003		x	
27016		x	
27059	x		
27060	x		
27061	x		

Table 3.1-18. Wells Deleted From Sampling Program (Page 4 of 4)

Region Well Number	Unable to Sample	Proximity	No Information
Central			
27074		x	
27075		x	
27076		x	
27077		x	
27078		x	
34003		x	
34004	x		
34005		x	
34006		x	
34007		x	
34010		x	
35005		x	
35016		x	
35017		x	
35035	x		
35036		x	
35053		x	
35054		x	
35055	x		
35056		x	
35060	x		
35066		x	
35069		x	
35070		x	
35071		x	
35072	x		
36048		x	
36069		x	
36084		x	
36090		x	
36091	x		
36109		x	
36116	x		
36117		x	
36118		x	
36119		x	
36122		x	
36136		x	
36137		x	
36138		x	
36140		x	
36141		x	
36142		x	

3.2 GROUND WATER MONITORING PROCEDURES

3.2.1 SAMPLING PROTOCOL

Ground water sampling methodology and techniques adhere to USATHAMA Geotechnical Requirements with respect to sample collection, sample preservation, sample shipment, and chain-of-custody requirements.

3.2.1.1 Water Level Measurements

Static water level measurements will be obtained for all wells selected for the water level measurement network. Static water levels will be measured with Soil Test model DR-760A water level indicators. Total depths will be measured with bottom-weighted nylon coated steel measuring tapes. Measured values will be reported to the nearest tenth of a foot.

All pertinent information obtained during the water level measurement phase will be recorded on water level measurement forms (Figure 3.2-1) and kept in a bound field notebook. The following information for each well will be included:

- Well number;
- Casing diameter;
- Date and time (24-hour system);
- HNU readings (background and in well casing);
- Stick-up height;
- Water level;
- Total depth;
- Measuring device;
- Sampler's initials;
- Casing volume; and
- Pertinent comments (e.g. condition of well).

Field crews will verify that the correct well has been located by comparing the total depth measured in the field to the value recorded on the well Summary Data Sheet. Values which do not correspond may indicate that the well is obstructed. Crews will attempt to "fish" obstructions by lowering a hook down the well. In extreme cases a winch may be required. Ropes used for "fishing" will be discarded after use.

RECORD OF ACTIVITIES AT WELL SITES
WATER LEVEL MEASUREMENTS

PROJECT ______________________________ PROJECT NUMBER ______________________

LOCATION ______________________________ SUPERVISOR ______________________

Well No.	Casing Diameter (Inches)	Date	Time	HNU Reading		Stick Up		Water Level		Total Depth (Feet)	Measuring Device	Sampler	Comments	Casing Vol. (Gal)
				Background	in Casing	(Feet)	(Tenths)	(Feet)	(Tenths)					

Figure 3.2-1
RECORD OF ACTIVITIES AT WELL SITES-
WATER LEVEL MEASUREMENTS

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

3.2.1.2 Water Sampling

All pertinent data obtained during ground water sampling will be recorded on Field Sampling Data sheets (Figure 3.2-2) and kept in a bound field notebook. The following information for each well sampled will be included:

- Well number;
- Date and time (24-hour system);
- Pertinent observations (e.g., weather, well condition);
- Station elevation;
- Stick-up height;
- Static water level and well depth;
- Casing diameter;
- Number of gallons per casing volume;
- Screened interval;
- HNU readings;
- Pump depth, measured pumping rates, total pumping time and total volume of water removed;
- Characteristics of the water (color, odor, etc.);
- Measurements of pH, temperature and conductivity;
- Identification of field equipment;
- Sampling description (number of bottles, sample fractions, sample depth);
- Field notebook number; and
- Signature of samplers and field team coordinator.

Field meters will be calibrated at the beginning of the day and once again during each day of sampling. These data will be recorded in the field notebook.

Records will be kept of all wells visited, including those found to be dry or constricted such that sampling is impossible. Dry wells will include those wells with the water level below the bottom of the screening interval.

At the conclusion of each day of sampling, the Field Team Coordinator will review each page of the field notebook and corresponding Field

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.
ENVIRONMENTAL PROGRAM AT ROCKY MOUNTAIN ARSENAL

RECORD OF ACTIVITIES AT WELL SITE
FIELD SAMPLING DATA SHEET

PROJECT ______________________ PROJECT NUMBER ______________________
WELL NUMBER ______________________ DATE ______________________
LOCATION ______________________ SAMPLERS ______________________
DATE DEVELOPED ______________________ ______________________
SUPERVISOR ______________________

STATION ELEVATION ______ WELL STICK UP ______ WATER LEVEL ______ WELL DEPTH ______
CASING DIAMETER ______ CASING VOLUME ______ SCREENED INTERVAL ______
HNU READING (BACKGROUND) ______ (WELL HEAD) ______
EVIDENCE TAPE ON SAMPLE KIT INTACT ☐YES ☐NO

Time	Pumping Rate (Gal./Min)	pH Units	Conductance umhos / cm	Temp. (°C)	Cumulative Volume of Water Bailed: Gallons	Cumulative Volume of Water Bailed: Casing Volumes	HNU Reading: Location	HNU Reading: Value	Comments

FIELD EQUIPMENT:
Eh / pH meter ______________ Serial No. ______________
E.C. meter ______________ Serial No. ______________
Pump ______________ Serial No. ______________
Water Level Meter ______________ Serial No. ______________
Temperature Measure ______________
Filter Apparatus ______________ Filters ______________
Bailer ______________ Size ______________
Calibration:

SAMPLING DESCRIPTION:
No. of Bottles ______________
Fractions (Circle)
C V V V V W
W W DB DC NF
Sample Depth ______________
Field Notebook No. ______________
Discharge Water Containerized ☐Yes ☐No

Figure 3.2-2
FIELD SAMPLING DATA SHEET

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Sampling Data sheet for errors and omissions and will then sign each data sheet.

A detailed step-by-step methodology will be developed and distributed to the field crews. This methodology will be reviewed and the field crews will be instructed in its proper implementation. Each field team will be supplied with a full set of sampling equipment. All four inch wells will be purged with a utility sampling vehicle equipped with a Standard classified 3 inch pump. Two inch wells will be evacuated with ISCO Model 2600 bladder-type submersible pumps. All pumps are powered with compressed air furnished by either gas driven compressors or electric compressors coupled with generators. Each team will be issued a pump, stainless steel bailers of varying lengths, Soil Test model DR-760A water level indicator, pH meter, thermocompensator, and electrical conductivity meter. Geotech filter setups will be issued for the collection of metals fractions. Back-up meters, standardization fluids, and miscellaneous spare equipment parts will be kept at the site command trailer.

All downhole equipment will be thoroughly cleaned with COR approved water prior to and between sampling each well. Bailers and stainless steel buckets will be cleaned in approved decontamination water mixed with trisodium phosphate, rinsed with approved water and triple rinsed with distilled water. All other equipment will be cleaned by triple rinsing with distilled water. All decontaminated equipment will be placed on clean plastic sheeting when not in use. In addition, bailers and pumps will be stored in clean polybutyrate tubes.

All equipment at the well site will be kept on clean plastic sheeting to reduce the potential for cross contamination. One sheet will be specifically designated for clean equipment. When bailing, care will be taken to ensure that the rope contacts neither the ground surface nor the outside of the well casing. A new rope will be used at each well and discarded when sampling is complete.

Where wells are being purged or sampled through the use of a submersible pump, the depth at which the pump is set will be determined by the relationship between the elevation of the water level and the elevation of the well screen. If the water level is within the screened interval or if the well is likely to be dewatered, the pump will be set just above the bottom of the well, the exact distance to be determined in accordance with the pump manufacturers recommendations (usually about 1 ft). If the water level is above the screened interval, the pump will be set several feet below that level. In this manner stagnant water near the water surface will be effectively removed and replaced by ground water from the aquifer.

3.2.1.3 Sampling Procedures

The following is a summary of the sampling procedures to be employed in Task 4:

1. Sampling crews receive labeled sample kits from Field Team Coordinator;
2. Record well number, date, pertinent information (e.g., weather, well conditions) station elevation, casing diameter, screened interval, field equipment identification (manufacturer, I.D. number);
3. Measure and record well stick-up, depth to water, total well depth, HNU readings, and calculate well casing volume;
4. Lower submersible pump to a few feet below the maximum drawdown or to the bottom of the well. If well is constricted above water level and pump will not pass, lower bailer to a few feet below water level. Record depth to pump or bailer;
5. Pump or bail five well casing volumes out of well. Measure and record time, pH, conductivity, and temperature after each well volume. Measure and record HNU readings by obtaining frequent background, wellhead and discharge water values. If well is located within a known contamination plume or if HNU readings are obtained above background level discharge, water will be disposed of in barrels. Otherwise water may be discharged on the ground at a minimum distance of 50 ft from the wellhead;

6. Measure and record pumping rate, total pumping time, and total volume purged;
7. Remove pump after purging is completed or if well is dewatered;
8. Sample immediately, or if well was dewatered, sample when water level has recovered. Sample using a bottom-filling stainless steel bailer, measure pH, conductivity, and temperature of water sample (obtained from bailer used for sampling). Record time and measured values on sampling sheet, in field notebook, and on sample labels;
9. Decant portion of water into sample bottles; cap bottles, agitate bottles and discard water. Fill rinsed sample bottles directly from bailer. Record sample depth;
10. Place bottles in ice chest;
11. Complete chain-of-custody forms; and
12. Sign and date well sampling form.

Prior to sampling, the pump will be removed from the well to provide access for the bailer. The pump should be equipped with a check valve so that water in the pump and pipe will not drain back into the well.

Wells constricted such that the pump cannot be lowered to the maximum drawdown will be evacuated by bailing. Such wells will be purged by removing a minimum of five casing volumes or the amount of water that can be removed in a standard working day.

A portion of the ground water will be collected in a clean, preferably disposable, container so the measurements of pH, temperature, and conductivity can be made. In addition, the color and odor of the ground water and other pertinent observations will be recorded.

The ground water will be sampled using a clean, bottom-filling or stainless steel bailer in a manner such that aeration and oxidation of the samples is minimized. A portion of the water will be decanted into the sample bottles, capped, agitated, and then discarded. The water will then be decanted into the sample bottles.

Each sample will be assigned a unique sample number. A sample typically will consist of several sample fractions collected in separate bottles labeled with a single sample number. The fractions are analyzed for different sets of parameters. Volatile organic fractions will be collected first then the remaining fractions designated for each well. Metals fractions will be filtered in the field using 0.45 μm membrane filters and preserved with dilute nitric acid to pH 2.0.

Each sample container will have a preprinted label. The labels will include the project number, sample number, date, time, sampler's initials, pH, conductivity, and preservations (if any). Samples will be placed in ice chests and will be kept below 4°C.

3.2.1.4 Sample Containers and Preservation

Sample containers and preservatives used in the sampling will be in accordance with USATHAMA specifications. These materials will be prepared and provided by the project laboratories.

In general, sample fractions for organic analysis will be collected in amber glass bottles with Teflon®-lined caps. Those for inorganic analysis will be collected in polyethylene bottles. Bottles for volatile organic analysis (VOA) will be filled to overflow and then tightly capped to avoid the presence of air bubbles. Air space may be left in the other sample bottles to allow for addition of preservatives, where necessary.

Care will be taken to prevent cross contamination of sample containers. Caps, open containers, or Teflon® liners that are dropped will be discarded and replaced. This replacement will be recorded in the field notebook. No samples will be collected when blowing dust is observed. Sampling will also be stopped in the event of rain or snow unless protective measures can be taken to prevent any possible dilution and/or contamination of the sample. All protective measures must first be approved by the site quality assurance officer.

3.2.1.5 Chain-of-Custody

Chain-of-custody forms will be issued with corresponding sample kits by the Field Team Coordinator. Each sample will be accompanied by two separate chain-of-custody forms; one form for sample fractions sent to ESE-Gainesville and one for fractions analyzed at ESE-Denver (Figures 3.2-3 and 3.2-4). These forms are an inventory of the samples and of those persons with access to the samples. They will be transported with the samples at all times. Possession of the samples will begin with the sample collectors. All subsequent transfers of the samples will require that the relinquisher and the receiver sign, date, and record the time of transfer of the chain-of-custody forms.

Data on the chain-of-custody forms will be completed by the Field Team Coordinator and will include the sample number, collection date and time, fractions collected, measured values of pH and conductivity, sample depth, well stick-up, and location and value of the highest encountered HNU reading. The Field Team Coordinator will obtain this data from the Field Sampling Data Sheets transmitted by the sampling teams.

3.2.1.6 Sample Shipment

By the end of each sampling day all samples will have been brought back to the sample handling trailer for packaging. The Field Team Coordinator will complete the chain-of-custody forms and review field notebooks and data sheets for errors and omissions.

Sample fractions designated for analysis by ESE-Gainesville will be re-packaged into heavy-duty coolers with ice to maintain a sample temperature of 4°C. ESE-Denver sample fractions will be similarly re-packaged into a separate cooler. Chain-of-custody forms will be placed in waterproof bags in their corresponding coolers. All coolers will be sealed and wrapped in accordance with individual shipping requirements. Evidence tape will be placed across each cooler designated for ESE-Gainesville analysis to ensure that the contents are not violated during shipping. The last person to sign the chain-of-custody form for each cooler will sign and date the evidence tape. The chain-of-custody forms for the ESE-Denver coolers will be signed over to the transport courier.

USATHAMA TASK 4 LOGSHEET FOR SENDING SAMPLES TO

ESE GAINESVILLE

ENVIRONMENTAL SCIENCE & ENGINEERING
PROJECT NUMBER: 85930420

PROJECT NAME: RMA - TASK 4

STORET MAP # 5469 TASK 4
LAB COORD. HUGH PRENTICE (904) 332-3318

FG NAME	ESE #	STAID	FRACTIONS (CIRCLE)	SAMPLE COLLECTION DATE / TIME	PH / COND	SAMPLE DEPTH	HNU READING/ LOCATION
			C V V V V W W W DB DC NF				
			C V V V V W W W DB DC NF				
			C V V V V W W W DB DC NF				
			C V V V V W W W DB DC NF				
			C V V V V W W W DB DC NF				
			C V V V V W W W DB DC NF				
			C V V V V W W W DB DC NF				
			C V V V V W W W DB DC NF				
			C V V V V W W W DB DC NF				
			C V V V V W W W DB DC NF				

NOTE
- -CHANGE OR ENTER SITE ID'S AS NECESSARY; UP TO 4 ALPHANUMERIC CHARACTERS MAY BE USED
- -CIRCLE FRACTIONS COLLECTED ENTER DATE, TIME, FIELD DATA (IF REQUIRED), HAZARD CODE AND NOTES
- -HAZARD CODES: I = IGNITABLE C = CORROSIVE R = REACTIVE T = TOXIC WASTE H = OTHER ACUTE HAZARD; IDENTIFY SPECIFICS IF KNOWN
- -PLEASE RETURN LOGSHEETS WITH SAMPLES TO ESE

RELINQUISHED BY: (NAME / ORGANIZATION / DATE / TIME)	RECEIVED BY (NAME / ORGANIZATION / DATE / TIME)
1	
2	
3	

OTHER FIELD NOTES: DB AND DC FRACTIONS SENT TO ESE DENVER LAB
NF FRACTION STORED AT DENVER LAB

Figure 3.2-3
USATHAMA TASK 4 SAMPLE LOGSHEET

SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

USATHAMA TASK 4 LOGSHEET FOR SENDING SAMPLES TO
ESE DENVER

ENVIRONMENTAL SCIENCE & ENGINEERING
PROJECT NUMBER: 85930420

PROJECT NAME: RMA - TASK 4

STORET MAP # 5489 TASK 4
LAB COORD. HUGH PRENTICE (904) 332-3318

FG NAME	ESE #	STAID	FRACTIONS (CIRCLE)	SAMPLE COLLECTION DATE / TIME	PH / COND	SAMPLE DEPTH	HNU READING / LOCATION
			DB DC NF				
			DB DC NF				
			DB DC NF				
			DB DC NF				
			DB DC NF				
			DB DC NF				
			DB DC NF				
			DB DC NF				
			DB DC NF				
			DB DC NF				

NOTE
- CHANGE OR ENTER SITE ID'S AS NECESSARY; UP TO 8 ALPHANUMERIC CHARACTERS MAY BE USED
- CIRCLE FRACTIONS COLLECTED. ENTER DATE, TIME, FIELD DATA (IF REQUIRED), HAZARD CODE AND NOTES
- HAZARD CODES. I = IGNITABLE C = CORROSIVE R = REACTIVE T = TOXIC WASTE H = OTHER ACUTE HAZARD, IDENTIFY SPECIFICS IF KNOWN
- PLEASE RETURN LOGSHEETS WITH SAMPLES TO ESE

	RELINQUISHED BY: (NAME / ORGANIZATION / DATE / TIME)	RECEIVED BY (NAME / ORGANIZATION / DATE / TIME)
1		
2		
3		

OTHER FIELD NOTES: STORE NF FRACTION

Figure 3.2-4
SAMPLE LOG SHEET

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

The ESE-Gainesville sample fractions will be shipped by air freight on a daily basis to ensure that sample holding times are not exceeded. Sampling will be scheduled such that the samples can be shipped in a timely manner.

3.3 SURFACE WATER

As part of the Task 4 Survey, surface water data will be collected and compiled. The surface water program will be designed consistent with the technical elements established for the task and consequently satisfy the overall task objectives.

Task 4 surface water monitoring activities will be two-fold. Separate efforts will be established to determine both the surface water mass balance and the water quality requirements of the surface water phase of the task.

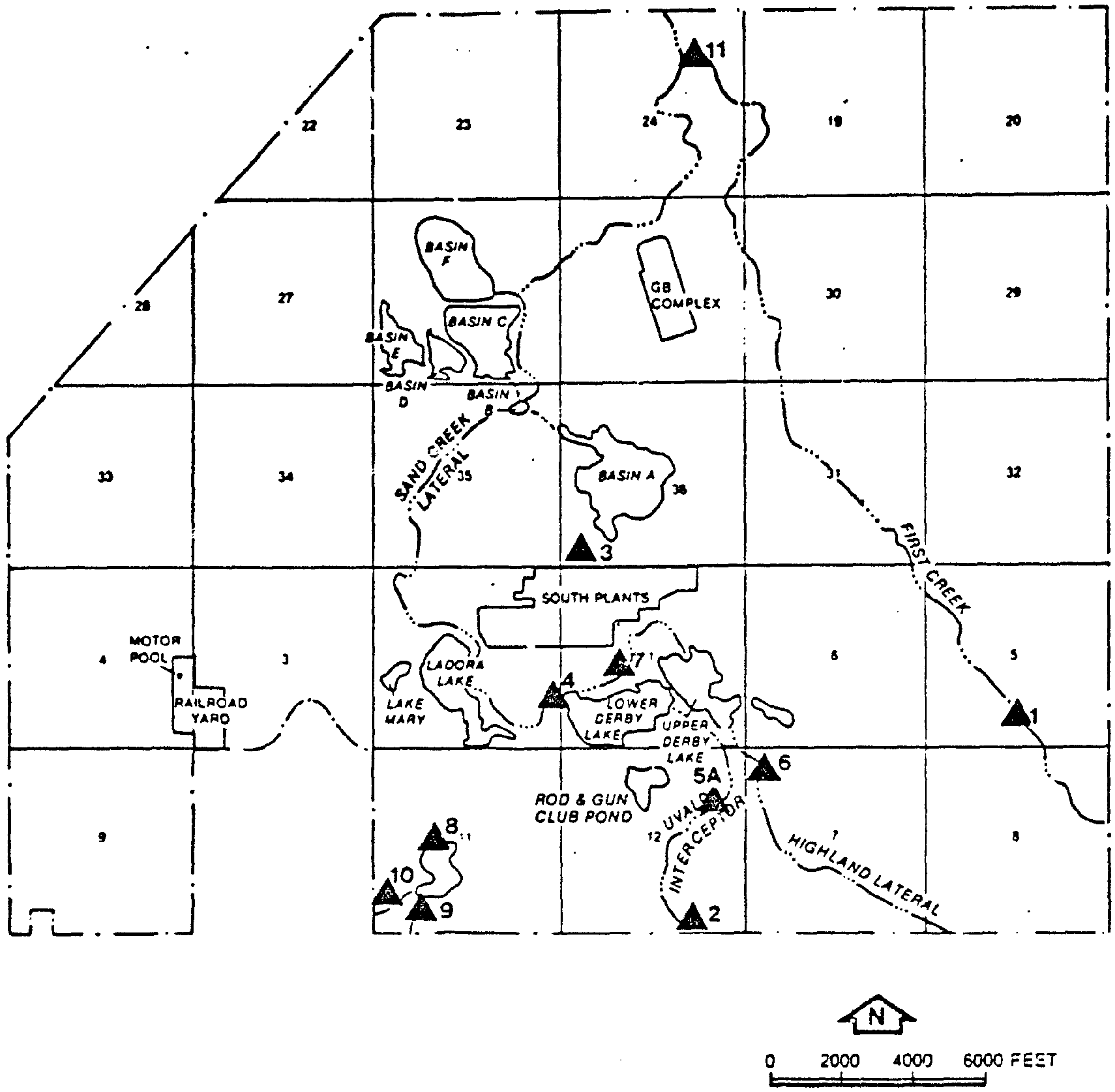
3.3.1 WATER QUANTITY

The water quantity portion of the Task 4 Survey is designed to determine a surface water mass balance for RMA. Efforts will be directed to the collection, reduction, and compilation of stream flow and precipitation data.

3.3.1.1 Water Levels and Discharge Rates

Water level measurements will be obtained at eleven monitoring stations currently established across RMA (Figure 3.3-1). Data will be recorded on preprinted forms (Figure 3.3-2). Data will be produced through the operation of Stevens Type-F continuous water level recorders. The recorders are equipped with battery-operated clocks, horizontal drum, 1:5 gage scale, and have a chart precision of 0.10 ft. These recorders have been modified and calibrated for weekly operation.

To protect the floats and dampen the fluctuations caused by wind and turbulence, the recorders are housed in stilling wells. The structures are located on the streambanks, except in the case of the Havana Interceptor which has the well located in the center of the canal. The inlets to the wells consist of two horizontal pipes with a lower inlet



▲ STREAM FLOW MONITORING STATION

1 First Creek (entering RMA)
2 South Uvalda Interceptor
3 Basin A Inflow
4 Ladora Weir
5A North Uvalda Interceptor (relocated)
6 Highline Lateral
7 South Plants Ditch
8 Havana Detention Pond
9 Peoria Ditch
10 Havana Interceptor
11 North First Creek

Figure 3.3-1
STREAM FLOW MONITORING STATIONS

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

STREAM GAGING FORM

Station ID ______________________ Date ______________________

Personnel ______________________ Time Start __________ Time Stop __________

Precipitation Past Day ______________________

Weather Conditions Now ______________________

Stream Appearance (include water condition, presence of ice, debris, etc.) ______________________

____

Gaging Location (Sketch Location On Back) ______________________

____

Staff Gage Reading: Start ______________________ Stop ______________________

Meter Used ______________________ Units ______________________

Left Bank (L.B.) and Right Bank (R.B.) are determined facing upstream

L.B. Water Edge On Tape ______________________ R.B. Water Edge On Tape ______________________

TAPE READING (ft)	UNIT WIDTH (ft)	DEPTH (ft)	READING COUNTS / TIME	VELOCITY (ft/sec)	DISCHARGE (cfs)	COMMENTS

Collected by ______________________
Signature Date

Checked by ______________________
Signature Date

Figure 3.3-2
STREAM GAGING FORM

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

below the lowest water elevation and an upper inlet which would be capable of functioning should the lower one become clogged during high flows. The steel housing is contained in a 6 in thick concrete base to prevent ground water infiltration and stream water outflow. To protect the gages from weather and vandalism, all devices are contained in locked instrument shelters.

The datum of the gages will be arbitrarily located at an elevation below the lowest possible water level. This will preclude the possibility of negative water level values. The datum selected will be referred to a benchmark of known elevation so the arbitrary datum may be recovered if gage and reference marks are destroyed.

Water surface elevation of Upper Derby, Lower Derby, Ladora, and Mary Lakes will also be monitored. Levels will be obtained through observation of staff gages installed at the lakes. Stage-volume curves will be utilized to convert measurements to lake stage. A survey of Havana Pond was conducted. This information along with that obtained from the continuous recording station were used to construct stage volume and stage area curves.

All open channels have been modified by the installation of artificial control structures. These control structures have caused some erosion of the banks and downstream channels. These will be stabilized by using rock gabions and riprap. To the extent possible without rebuilding the entire structures, the following conditions will be met or approximated within the constraints of practicality:

- The shape of the structure will permit the passage of water without creating undesirable disturbances in the channel above or below the control;
- The structure will be of sufficient height to eliminate the effects of variable downstream conditions;
- The profile of the crest of the control will be designed so that a small change in discharge at low flows will cause a measurable change in stage; and

- The control will have structural stability and should be permanent.

The installation of such artificial controls tends to stabilize the stage-discharge relation and thereby simplify the procedure of obtaining accurate records of discharge. Specifically, of the 10 channels, 5 are natural channels equipped with concrete controls somewhat higher than the downstream channel bottom elevation. In most cases, the controls are lower at the center of the channel than at either bank and form a slightly V-shaped cross section. The stream gage stations which are equipped with these concrete controls are North and South First Creek, North and South Uvalda Ditch, and Peoria Interceptor.

The five remaining channels are Ladora Weir, Havana Interceptor, South Plants Ditch, Highline Lateral, and Basin A. The Ladora Weir location is equipped with a sharp crested weir and Havana Interceptor is a large concrete-lined trapezoidal-shaped canal. The South Plants Ditch and Highline Lateral sites are located just upstream from the concrete-lined diversion structures. The Basin A structure is a vee notch weir located in a small channel.

Discharge will be calculated for the 10 open channel monitoring stations and obtained directly from the Ladora Lake and Sewage Treatment Plant flow meters. Measurements of flow and the corresponding simultaneous stage recording will be utilized to construct stage-discharge rating curves for the gaging stations at North and South First Creek, North and South Uvalda, Peoria and Havana Station. In order to determine the discharge corresponding to different stage heights, the velocity and area of each stream must be determined. The velocity will be measured at a number of points across the stream at six-tenths of the channel depth. Using this datum, as well as the depth at each point, the mid-section method of calculating the discharge for partial sections will be used. Six cross-section measurements have been made at each station to produce a verifiable rating curve. Gaging stations at the Highline Lateral, Basin A Inflow, Ladora Weir, and the South Plants Ditch utilize weirs and flumes for which rating curves have previously been developed.

In the event the streamflows are too swift to permit wading into the stream, a "slope-area" approach will be used. The slope-area technique is a method of calculating discharge from Manning's equation, using data for cross-sectional area of flow hydraulic radius, friction slope of the flow, and an estimated roughness coefficient (National Handbook of Recommended Methods for Water-Data Acquisition). The curves will be revised each time channel conditions are altered. Because rating curves will not be completed until near the end of the project, a Manning's equation approach will be used to estimate flows and flood discharges. The cross-sectional area will be determined from surveys. The roughness coefficient will be determined using data from direct measurements where discharge and cross-sectional area are known. In conjunction with this, a float method will be used to determine velocities. The method involves measuring the amount of time required for a floating object to travel a known length of straight channel. A coefficient of 0.85 is commonly used to convert surface velocity to mean velocity. This coefficient will be calibrated on days of high flow when both methods can be used. Measurements made utilizing this method should be accurate within 10 percent.

3.3.1.2 Precipitation

Two precipitation gages have been installed at RMA. These are used, in conjunction with precipitation measurements obtained at National Weather Service stations at Stapleton Airport and at Brighton, to determine the precipitation input to the RMA surface water. The gages are of the tipping bucket variety and are attached by cable to event recorders.

3.3.1.3 Significant Storms and Large Flows

Large flows of water entering RMA are not common, but may occur several times in an average year. Such flows enter RMA primarily through First Creek, Uvalda Interceptor, Havana and Peoria Interceptors and possibly Highline Lateral. All of these flows enter RMA through well defined channels from the south or southeast. Other flows may reach RMA as overland flow in less well defined channels entering RMA from the south. Plans for monitoring large flows have been developed for the main channels only.

Although the hourly rate of rainfall may not be heavy, storms can produce large amounts of runoff. If such a storm lasts for more than one day, significant runoff can be anticipated. Thunderstorms primarily occur in the summer months. The amount of precipitation from thunderstorms is roughly related to the surface dew point and the lifting index as computed from the routine upper-air soundings.

Alert Programs

Heavy runoff expected as a result of continuous rainfall can be predicted by daily weather forecasts. Temperature, dew point, and lifting index computed from atmospheric soundings can be used to predict thunderstorm activity. In addition, the location of specific storms can be tracked by radar at weather service offices. A telephone alarm system connected to a main gage on RMA may also be used to alert personnel of potentially significant runoff events. Such procedures will enable personnel to be onsite to monitor peak flow conditions.

The points at which flow is to be measured on RMA as a first priority are:

- o First Creek at the southern gaging station;
- o Uvalda Interceptor at the southern gaging station;
- o Peoria Interceptor; and
- o Havana Interceptor.

Data from these four points will provide a good estimate of the quantity of water flowing onto RMA. A secondary check on the Havana and Peoria inflows will be provided by measuring water flowing into Havana Pond. All other gaging station sites will be given secondary priority. It is anticipated that during extreme events sufficient personnel will be onsite to monitor both first and second priority points.

Streamflow measurements performed during periods of high flow will primarily be by a slope-area technique when the flows are greater than can safely be measured using a current meter. Velocity measurements will be performed using a float technique. The floats utilized will be fresh oranges or floats of a similar nature which will be somewhat imbedded in the flows. Floats will be placed in the stream at a given mark, and the

time required for it to reach another set point (about 200 ft downstream) will be noted.

Maximum stage recorders will be utilized to obtain the maximum stage reached during the storm event. This type of recorder will also be utilized to compute the maximum flow using the slope-area concept.

3.3.1.4 Scheduling

Monitoring activities will require personnel onsite as dictated by climatological conditions. As recorders have been calibrated for weekly operation, personnel will be onsite a minimum of once a week to collect water level and streamflow data. During this time routine maintenance of apparatus and structures will be performed.

Currently, numerous ESE and subcontractor personnel are involved on a daily basis with ongoing field activities at RMA. The onsite staff will notify parties directly involved in surface water monitoring of impending storms and uncontrolled actions affecting the surface water budget (surface water diversion, overflows, etc.). In addition to making daily measurements and observations and maintaining current stage-discharge curves, personnel will be onsite to monitor conditions continuously during major storm events.

Water quantity data will be reduced daily and compiled on both a weekly and monthly basis.

3.3.2 WATER QUALITY

Quarterly sampling will be performed as part of the surface water portion of the Task 4 Survey. Samples will be collected at 30 locations across RMA (Figure 3.3-3).

3.3.2.1 Sampling Protocol

Data from surface water sampling will be recorded on water sampling forms (Figure 3.3-4) similar to those utilized in the ground water sampling program. These data will include an accurate description of the point sampled, date, sample number, field parameter measurements (pH,

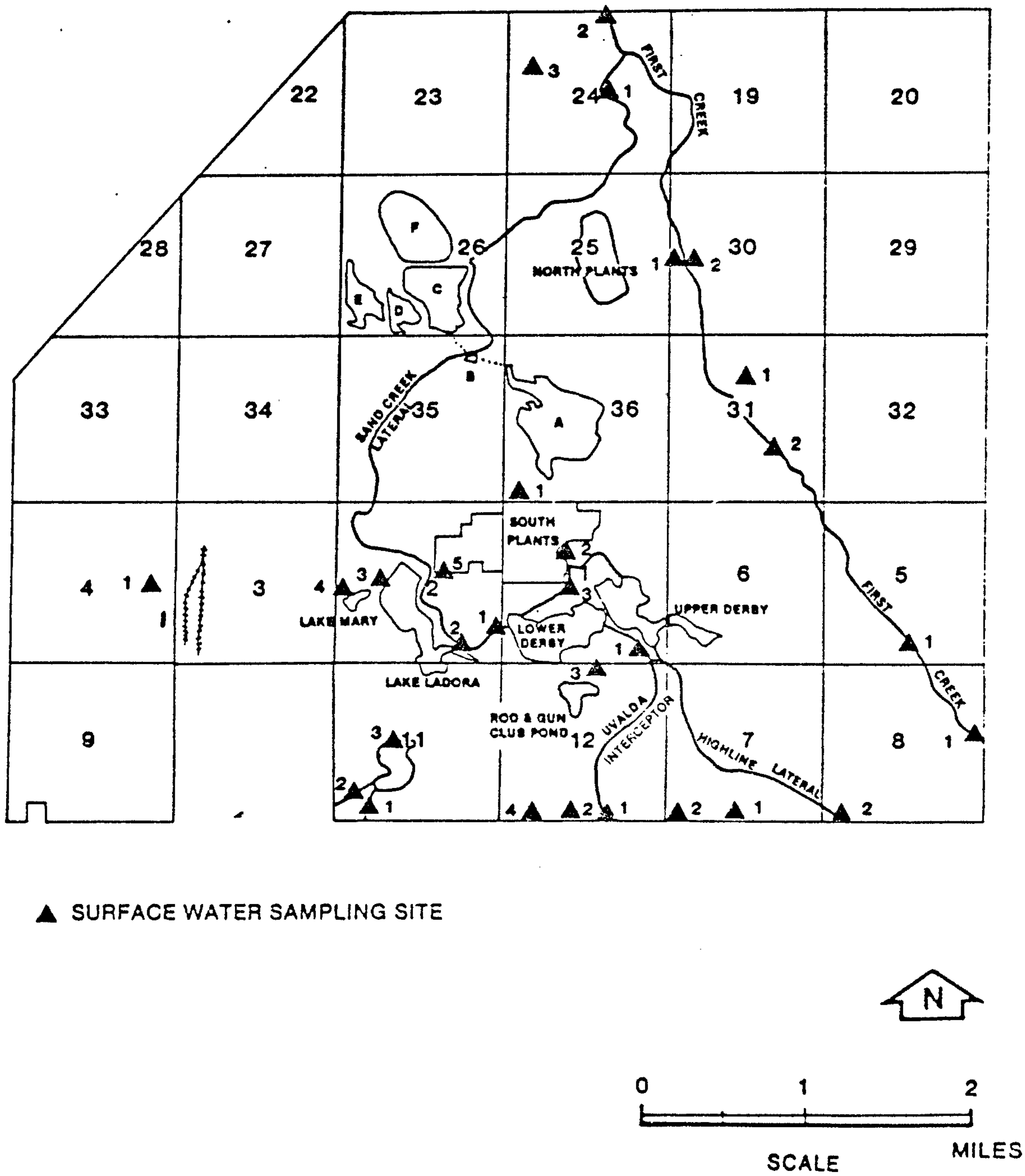


Figure 3.3-3
LOCATIONS OF SURFACE WATER SAMPLING SITES

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.

SURFACE WATER SAMPLING FORM

Station ID ____________________ Date ____________________

____________________ Sample Time ____________________

Collected by ____________________ ESE Sample Number ____________________

Sample Splits Collected for ____________________

Fraction Sampled C V V V DB DC W1 W2 W3 ___ ___ ___ ___

Visual Appearance of Stream/Lake ____________________

Visual Appearance of Sample ____________________

Sampling Location ____________________

____

Sampling Method ____________________

Discharge Measure With ____________________

Discharge ____________________ Staff Gage Reading ____________________

Weather Conditions Now ____________________

Precipitation Past Day ____________________

Comments ____________________

____

FIELD CHEMISTRY

Calibration: pH Meter Used: ____________________

pH 7.00 = ________ at ________ °C, pH 10.00 = ________ at ________ °C

Conductance Meter Used: ____________________

Standard ________ umhos/cm at 25°, Reading ________ umhos/cm at ________ °C

Time	Temp. °C	pH	Conductance	Conductance at 25°C
			at °C	

Remarks: ____________________

____

____

____

____

____

Collected by ____________________
Signature Date

Checked by ____________________
Signature Date

Figure 3.3-4 SURFACE WATER SAMPLING FORM	Prepared for: U.S. Army Program Manager's Office For Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland

temperature, and specific conductivity), sample fractions, and the sampler's name.

The sample will be collected either directly in the sample container or in a bailer from which the water is decanted into the sample bottles. Labels with the sample number and date will be attached. Sample number and date will also be written on the sample bottles as described in Sections 3.9.1 of the Task 1 Technical Plan. Samples will be stored on ice in coolers at 4°C.

3.3.2.2 Sample Containers and Preservation

Surface water samples will be preserved as required by USATHAMA Geotechnical Requirements. In general, samples for organic analysis will be collected in amber glass bottles with Teflon®-lined caps. Samples for inorganic analysis will be collected in polyethylene bottles.

3.3.2.3 Chain-of-Custody

Chain-of-custody forms will be completed by the samplers and checked by the Field Team Leader according to the procedure described in Section 5.0 of the Task 1 Geotechnical Plan.

3.3.2.4 Sample Shipment

Samples will be packaged and shipped according to the procedures described in Section 5.0 of the Task 1 Geotechnical Plan. Chain of-custody forms will accompany all samples.

3.3.2.5 Schedule

As stated, samples will be collected on a quarterly basis. In the event that a sample cannot be collected as a result of dry conditions and no flow, sampling will be performed during periods of major rainfall when streamflow is renewed. If any abnormalities (oil slicks, unusual coloration, etc.) are observed, a sample will be collected at that time.

4.0 CHEMICAL ANALYSIS

The objectives of the chemical analysis program are to provide PMO-RMA with reliable, statistically supportable, and legally defensible chemical data regarding type and level of contamination in surface and ground waters at RMA.

The current Task 4 program requires various analytical techniques to be performed on collected samples to achieve a quantitative determination of water quality, a semi-quantitative confirmation of analytes identified by quantitative methods, and a semi-quantitative identification of non-target compounds.

An initial schedule of 24 chemical parameters originally proposed for quantitative analysis was expanded to include additional organic and inorganic species. The modified analytical schedule of 50 substances includes seven organochlorine pesticides, DCPD, MIBK, DIMP, DMMP, DBCP, six organosulfur compounds, five volatile aromatics, 12 volatile organohalogens, and 15 inorganic parameters (Table 4.0-1). Semi-quantitative methods (GC/MS) will be used to screen for twenty-four purgeable and twenty-five extractable compounds (Table 4.0-2). The current analytical list was derived from various sources. These sources include:

- o An evaluation of contaminant source characteristics at RMA and compounds attributable to activities at these sites;
- o A review of the historical chemical data and recognition of compounds previously detected; and
- o Additional input from the MOA parties.

As a result of the dynamic nature of the Task 4 program, the ISP, underwent various analytical modifications. Table 4.0-3 lists the wells sampled under the ISP and the analyses performed.

Table 4.0-1. Chemical Analysis - Task 4 (Page 1 of 2)

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	Method
Organochlorine Pesticides		Quantitative	EPA 608	CAP-GC/ECD
Aldrin	Extract as quickly as possible. (No more than 7 days). Analyze within 30 days of extraction.			
Endrin				
Dieldrin				
Isodrin				
Hexachlorocyclopentadiene				
p,p´-DDE				
p,p´-DDE				
Volatile Organohalogens		Quantitative	EPA 601	PACK-GC/Hall
Chlorobenzene	14 days			
Chloroform	14 days			
Carbon Tetrachloride	14 days			
trans-1,2-Dichloroethylene	14 days			
Trichloroethylene (TCE)	14 days			
Tetrachloroethylene	14 days			
1,1 Dichloroethylene	14 days			
1,1 Dichloroethane	14 days			
1,2 Dichloroethane	14 days			
1,1,1 Trichloroethane	14 days			
1,1,2 Trichloroethane	14 days			
Methylene Chloride	14 days			
Organosulfur Compounds		Quantitative		PACK-GC/FPD-S
P-Chlorophenylmethylsulfone ($PCPMSO_2$)	Extract as quickly as possible. (No more than 7 days.) Analyze within 30 days of extraction.			
P-Chlorophenylmethylsulfoxide (PCPMSO)				
P-Chlorophenylmethylsulfide (PCPMS)				
1,4-Dithiane				
1,4-Oxathiane				
Dimethyldisulfide (DMDS)				
Volatile Aromatics		Quantitative	EPA 602	PACK-GC/PID
Toluene	14 days			
Benzene	14 days			
Xylene (o-, m-, p-)	14 days			
Ethylbenzene				

Table 4.0-1. Chemical Analysis - Task 4 (Page 2 of 2)

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	Method
DCPD/MIBK		Quantitative	EPA 608	CAP-GC/FID
Dicyclopentadiene/ Methylisobutylketone	Extract as quickly as possible. (No more than 7 days). Analyze extract within 30 days of extraction.			
DIMP/DMMP		Qualitative	EPA 622	PACK-GC/FPD-P
Diisopropylmethylphosphonate/ Dimethylmethylphosphonate	Extract as quickly as possible. (No more than 7 days). Analyze within 30 of extraction.			
DBCP		Quantitative		CAP-GC/ECD
Dibromochloropropane	14 days			
Inorganics		Quantitative		
Calcium	28 days		EPA 200	Inductively Coupled Plasma
Magnesium				
Sodium				
Potassium				
Cadmium				
Copper				
Chromium				
Lead				
Zinc				
Arsenic			EPA 206	AA-Hydride
Mercury			EPA 245	Cold Vapor
Chloride			EPA 300	Ion Chromatograph
Fluoride				
Sulfate				
Nitrate + Nitrite			-	Auto Analyzer

Source: ESE, 1985.

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	Method
eables		Semi-Quantitative	EPA 624	GC/MS
thylbenzene	7 days			
Benzene				
MIBK				
DMDS				
1,1-Dichloroethane				
1,2-ichloroethane				
1,1,1-Trichloroethane				
1,1,2-Trichloroethane				
Methylene chloride				
Chloroform				
Carbon tetrachloride				
trans-1,2-Dichloroethylene				
Toluene				
Chlorobenzene				
Tetrachloroehtylene				
Trichloroethylene				
m-Xylene				
o- and/or p-Xylene				
DBCP				
Dicyclopentadiene				
Bicycloheptadiene				
1,2-Dichloroethane				
hylene chloride				
ylbenzene				
ractables		Semi-Quantitative	EPA 625	GC/MS
Aldrin	Extract as quickly as possible. (No more than 7 days). Analyze extract within 30 days of extraction.			
Atrazine				
Chlordane				
PCPMS				
PCPMSO				
$PCPMSO_2$				
DBCP				
DCPD				
4,4'-DDE				
4,4'-DDT				
Dieldrin				
DIMP				
Dithiane				
Endrin				
HCCPD				
Isodrin				
Malathion				
Oxathiane				
Parathion				
Supona				
Vapona				
hlorophenol				
-Dichlorobenzene				
ethylphthalate				
-n-Octylphthalate				

Table 4.0-3. Sampling Schedule

	Existing Programs 360° Program (75 Wells)	Existing Programs RCRA (12 Wells)	Screening Program	RMA Wide Task 4 (150 Wells)	RMA Wide Fifth Quarter (150 Wells)
Aldrin		X*	X*	X	X*
Endrin		X*	X*	X	X*
Dieldrin		X*	X*	X	X*
Isodrin		X*	X*	X	X*
HOCPD			X*	X	X*
p,p´-DDT			X*	X	X*
p,p´-DDE			X*	X	X*
DBCP	X*	X*	X*	X	X*
DCPD	X*	X*	X*	X	X*
MIBK			X*	X	X*
DIMP	X*	X*	X*	X	X*
DMMP			X*	X	X*
$PCPMSO_2$		X*	X*	X	X*
PCPMSO		X*	X*	X	X*
PCPMS		X*	X*	X	X*
DMDS			X*	X	X*
Dithiane		X*	X*	X	X*
Oxathiane		X*	X*	X	X*
Toluene			X*	X	X*
Benzene			X*	X	X*
Xylene			X*	X	X*
Ethylbenzene			X*	X	X*
Chlorobenzene			X*	X	X*
Chloroform			X*	X	X*
CCl_4			X*	X	X*
1,2-Dichloroethylene			X*	X	X*
TCE			X*	X	X*
Tetrachloroethylene			X*	X	X*
Methylene chloride			X*	X	X*
1,1-Dichloroethene			X*	X	X*
1,1-Dichloroethane			X*	X	X*
1,2-Dichloroethane			X*	X	X*
1,1,1-Trichloroethane			X*	X	X*
1,1,2-Trichloeoethane			X*	X	X*
Cl	X*	X*	X*	X	X*
F	X*	X*	X*	X	X*
Ca	X*		X	X	X*
K	X*		X	X	X*
Mg	X*		X	X	X*
Na	X*		X	X	X*
N (Nitrate-Nitrite)	X*		X	X	X*
SO_4	X*		X	X	X*
Zn			X	X	X*
Cr			X	X	X*
Cd			X	X	X*
Pb			X	X	X*
Cu			X	X	X*
Hg			X	X	X*
As			X	X	X*
624/625				X	X

* To be performed on all wells.

Because the primary objective of the ISP is to establish a core monitoring network for continued Task 4 programs and future RMA activities, semi-quantitative analysis was deferred until discrepancies could be clarified. Subsequent quarterly sampling will be conducted utilizing a regional approach. An evaluation of both the historical data base and the ISP results indicated that RMA could be divided into four distinct areas (Figure 4.0-1) based on the occurrence of characteristic suites of chemical groups (Table 4.0-4). Each year, four quarterly sampling periods will follow the site specific regional schedule. Every fifth quarter, samples will be analyzed for the entire suite of 50 parameters. The fifth quarter will fall in the first quarter of the second year, the second quarter of the third year, and so on, thereby identifying any seasonal effects.

Wells for semi-quantitative screenings will be selected based on an evaluation of previous quarterly results. Wells demonstrating inconsistencies or discrepancies with regard to past results will be analyzed by GC/MS for confirmation of results. Wells possessing numerous detectio... or showing high baseline concentrations will be analyzed for non-target analytes. Approximately 20 to 30 percent of the quarterly sample load will be analyzed by semi-quantitative methods.

Defensibility and technical quality of the data will be assured by proper documentation of procedures used during the analytical survey. Sample preparation, materials, shipping, handling, chain-of-custody procedures, etc. will be consistent with those required in Task 1. Field QA/QC procedures are summarized in Table 4.0-5.

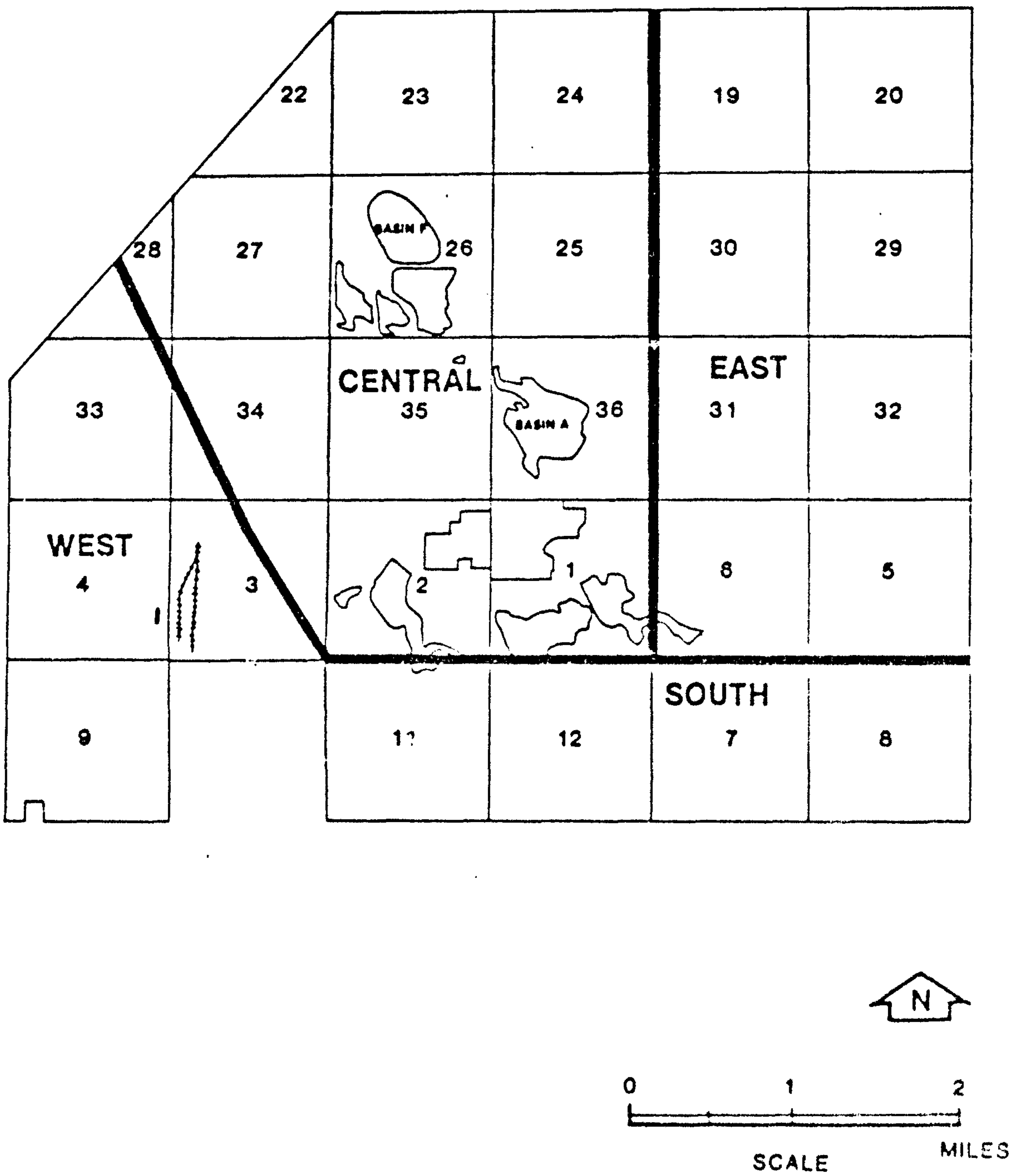


Figure 4.0-1
REGIONS OF RMA REQUIRING DIFFERENT ANALYTICAL SUITES FOR THIRD QUARTER (FY86) SAMPLING

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Table 4.0-4. Analytical Parameters Proposed for Third Quarter (FY86) Sampling

Analyte	Region*			
	East	South	Central	West
Organosulfur compounds	Yes	Yes	Yes	No
Organochlorine pesticides	Yes	Yes	Yes	Yes
DIMP	Yes	Yes	Yes	No
DCPD	Yes	Yes	Yes	No
DBCP	Yes	Yes	Yes	Yes
Purgeable organics	Yes	Yes	Yes	Yes
Chloride/Fluoride/Sulfate	Yes	Yes	Yes	Yes
ICP Metals				
(Cd, Cu, Cr, Pb, Zn)	No	No	Yes	Yes
Arsenic	No	No	Yes	Yes
Mercury	No	No	Yes	No
Other Inorganics	No	No	No	No

* Regions are outlined on Figure 4.0-1.

Table 4.0-5. Field QA/QC Procedures

QA Sample Type	Analytical Method	Required Frequency	Preparation
Volatile Trip Blank	M8	1 paint can with 3 volatile septum vials per day, each day samples for GC/MS verification are collected.	Transport filled blank volatile septum vials to field, open paint can and return to laboratory with samples.
Volatile Trip Blank	W8, Y8	1 paint can with 3 volatile septum vials per week, each week samples for GC analysis are collected.	Transport filled blank volatile septum vials to field, open paint can and return to laboratory with samples.
Rinseate Blank	S8, U8, T8, W8, Y8, X8, K8, L8, A8, AA8, B8, Z8, Q8	1 suite per week, each samples are submitted.	Decontaminate bailer used to collect samples. Pour deionized water into cleaned bailer, then transfer to sample bottles. Perform while onsite. Not applicable if dedicated bailer is used.
Field Blank	S8, U8, T8, W8, Y8, X8, K8, L8, A8, B8, Z8, Q8	1 suite per week, each week samples are submitted.	Pour organic free deionized water directly into sample bottles. Perform while onsite.
Duplicates	M8, BB8, S8, U8, T8, W8, Y8, X8, K8, L8, A8, AA8, B8, Z8, Q8	10% of all samples should be collected in duplicate, including GC/MS verification samples.	Collect 2 suites of sample bottles while onsite.

5.0 QUALITY ASSURANCE

Quality Assurance (QA) for Task 4 will be consistent with the Field/Laboratory QA Plan developed for Task 1 activities. The plan is project specific and describes procedures for controlling and monitoring sampling and analysis activities as required under Task 4. As designed, the Field/Laboratory QA Plan will ensure the production of valid and properly formatted documentation concerning the precision, accuracy, and sensitivity of each method used for USATHAMA sampling and analysis efforts. The plan is based on USATHAMA April, 1982 QA program requirements as modified by U.S. Army AMCCOM Procurement Directorate and ESE as well as certified analytical methods submitted to and approved by USATHAMA. The plan is presented in Appendix B of the Task 1 Technical Plan. Specific RMA QA/QC requirements are detailed in Section 5.0 of the same document.

6.0 DATA MANAGEMENT PLAN

Data for Task 4 will be handled according to the Data Management Plan in Volume I of the Task I Technical Plan, Contract Number DAAK11-84-D-0016. As outlined in the plan, field data will be entered into the Compaq Plus personnel computer in the ESE Denver office and transmitted to the Compaq in the ESE Gainesville office via telephone. The field data will be transferred to the IR-DMS, subjected to the Geotest data check routine, validated, and placed into Level 2. Sample number assignments, labels, and logsheets will be made in Gainesville and given to the sampling team. Samples shipped to laboratories will follow chain-of-custody procedures described in the Technical Plan. Data from lab analyses will be entered into the ESE Prime 750 computer, incorporated with certification and field data, and formatted into files according to the IR-DMS User's Guide. After validation these files will be sent to the Univac using the Tetronix or the Compaq Plus computer, run through the data-checking routine and elevated to Level 2.

7.0 SAFETY PROGRAM

The purpose of this section is to summarize the safety, accident, and fire protection standards, and to outline standard operating procedures to ensure the safety of all ESE and subcontractor personnel performing Task 4 activities at RMA. Responsibilities, authorities, and reporting procedures as designated for Task 4 are identical to those designed for Task 1 in Section 7.0 of the Task 1 Technical Plan.

The program addresses all of the requirement of DI-A-5239B and fully complies with requirements of the Occupational Safety and Health Administration (OSHA) and U.S. Army Material Command (AMC) Regulation 385-100, Army Regulation (AR) 385-10, and Department of Army Pamphlet (DA PAM) 385-1 for all activities to be conducted. The program also complies with the ESE Analytical Laboratory Safety Plan.

7.1 TASK 4 PROCEDURES

7.1.1 WASTE CHARACTERISTICS

In the 43 year history of RMA, many hazardous substances have been manufactured, stored, or demilitarized at the post. Key compounds include GB and other nerve agents, H and L blister agents, munitions, organochlorine pesticides and herbicides, phosgene, hydrazine, and toxic metals. Detailed information on many of these compounds is provided in Agent Fact Sheet, SMCRM Form 357 (RMA, 1984) and Military Chemistry and Chemical Agents, TM 3-215 and AFM 355-7 (Departments of Army and Air Force, 1963). Copies of this information are available at the support trailer at RMA.

7.1.2 GENERAL PROCEDURES

As Task 4 activities will be RMA wide, the program will be conducted in both uncontaminated and contaminated areas. In order to develop the most adequate Safety Plan possible an evaluation of each sampling and monitoring station will be made. This will result in each sampling and monitoring location being treated separately. Overall procedures and methods are outlined in the following sections.

An area of 30 ft will be established around all wells and surface monitoring/sampling sites. This will be considered a "hot zone" and all personnel entering this area will wear the prescribed level of protection. Before entering the "hot zone" all personal protective equipment will be checked for proper fit and operation.

In areas of known or suspected contamination the following decontamination procedures will be followed:

- Equipment decontamination will occur at the sampling site. Bailers, pumps, and other field equipment will be washed at the hotline using trisodium phosphate and water followed by a triple rinse with distilled water, and wrapped in a plastic bag.

- Field team members will have a two phase decontamination procedure. Outer clothing will be rinsed at the hot line. After this initial decontamination, field personnel will ride in the truck to the decontamination pad. At the pad, all disposable clothing will be removed and discarded into barrels. The field personnel will then ride into the support area enter the field wash trailer, shower, and change into street clothes.

To avoid contaminating the vehicle, the seats and floors will be lined with plastic at the beginning of each day and after lunch. When field personnel decontaminate at the decontamination pad, this plastic will be removed and discarded. The truck will then be considered clean.

When sampling wells and surface water and taking water level measurements in Section 36, the truck will be considered contaminated. The vehicle will then be decontaminated at the decontamination pad in Section 36 using the hot water pressure washer.

7.1.3 SURFACE WATER SAMPLING

Surface water within the boundaries of RMA will be sampled during Task 4. The major hazards during this activity are skin and eye contact with contaminated water as well as physically falling into a body of water.

As all surface water sampling will be done from the edge of the water body and not from a boat, the falling hazards should be minimal.

Levels of protection for the surface water sampling/monitoring portion of Task 4 are based on an evaluation of the respective locations by the Subtask Supervisor.

- Section 36 and South Plants--Field personnel will wear modified Level D protection while performing surface water sampling/monitoring in Section 36. Respirators will be readily available and equipped with Scott 642 OV-H cartridges. Saranex®-coated Tyvek® coveralls will be worn while conducting operations. Personnel will monitor the area with a photoionization detector to determine airborne organic vapor concentrations.
- Other areas--Field personnel will wear Level D protection at all other sampling monitoring sites. Protection will consist of inner and outer rubber gloves, steel toe and shank rubber boots, goggles for eye protection, and cotton overalls. Respirators will be readily available.

All sampling and monitoring efforts will be performed in teams of two. Before commencing activities, field personnel will check in at the safety trailer. While wearing Level D protection, samplers will avoid submerging their hands in water so deeply that water drains into the top of the gloves. Gloves should be taped at the wrists in modified Level D protection.

Levels of protection will be upgraded if the Safety Officer deems necessary.

7.1.4 GROUND WATER SAMPLING

Ground water from existing wells on RMA will be sampled by field team members. As with surface water sampling, skin and eye contact with contaminated water is a major hazard. Inhalation hazards are increased when the well is first uncapped due to a possible build-up in the well of

hazardous vapors, and during well purging as volatiles may be stripped from the water and become airborne.

Continuous monitoring with a photoionizaton detector will take place during well uncapping and purging activities. Field personnel will uncap wells from the upwind side. If an above background reading is detected during opening, team members will retreat to at least 30 ft away from the well for 10 minutes. This will allow the vapors to disperse. After 10 minutes, team members will again test the well with the photoionization detector.

If organic vapor concentrations are detected above background in the breathing zone during well sampling, respirators will be worn at all times or until the safety officer states that respirators may be removed. During both uncapping and pumping activities, if organic vapors are detected above 5 ppm in the breathing zone, work activities will cease immediately and team members will don Level B protection to complete the well sampling.

Levels of protection for the ground water sampling portion of Task 4 will be based on an evaluation of the respective sampling sites by the Subtask Supervisor or his representative. In general, modified Level D protection in the uncontaminated areas and full Level C or B protection in contaminated areas will be required. Levels will be adjusted as the Safety Officer deems necessary based on organic vapor levels and well history. During ground water sampling, field teams will consist of at least two persons. A first aid kit and fire extinguisher will be available at all times. Sampling teams will check-in at the safety trailer prior to commencing activities.

7.1.5 WATER LEVEL MEASUREMENTS

Field personnel performing water level measurements will don Level D protection to complete their activities. Respirators will be readily available. Personnel will uncap wells following the same procedures outlined in the previous section. The field team will continuously monitor for organic vapors using a photoionization detector. Personal

and respiratory protection may be modified based on organic vapor readings and well history.

7.2 CONTINGENCY PLANS

7.2.1 CHEMICAL AGENTS AND ORDNANCE

It is possible that during Task 4 activities field teams will encounter surety materials in ground and surface water. The most likely areas to encounter these materials are Section 36 and South Plants.

7.2.1.1 Monitoring Procedures for Surety

All water sampling teams will be supplied with detector paper from the M-18 A2 Field Kits. This paper changes color when dipped in surety contaminated water. Team members will test the water for surety during the removal of each casing volume and once during sampling.

In the event that chemical agents are detected, field personnel will follow the procedures as outlined in Section 7 of the Task 1 Technical Plan. Additional safety procedures regarding UXO, chemical agent incidents, emergency services, fire/spills, and accident reporting are also detailed in Section 7 of the Task 1 Technical Plan.

8.0 CONTAMINATION ASSESSMENT

In keeping with the scope of Task 4, evaluation of the data generated by the water quality/quantity survey will address five primary objectives:

- Definition of the nature and extent of surface and ground water contamination;
- Characterization of temporal and spatial variations in water quality;
- Verification of the USATHAMA RMA historical data base;
- Development of third and forth quarter monitoring programs based on ISP results; and
- Presentation of recommendations for continued long term monitoring.

In order to accomplish these objectives, hydrologic and chemical data generated by the water quality/quantity survey will be compiled and presented in tabular and graphical formats. In addition, historical chemical and geologic data will be reevaluated and presented in compatible formats. Review and comparison of the Task 4 and historical data will allow for evaluation of spatial and temporal contamination patterns and formulation of continued sampling programs. It is anticipated that additional detailed hydrogeologic and geochemical evaluation of these data will be performed under subsequent task orders.

Specific work elements envisioned for the contamination assessment include:

- Chemical and hydrologic data reduction and graphical presentation;
- Compilation and graphical presentation of historical chemical data;
- Qualitative comparison and identification of discrepancies between historical chemical data and Task 4 results; and
- Reevaluation of alluvial and bedrock structure and stratigraphy.

8.1 DATA REDUCTION

Under this work effort, all field and laboratory data obtained during the monitoring program will be compiled and presented. Level 2 data will be transmitted to the USATHAMA Edgewater Scientific Computer Center for inclusion in the RMA data base. In addition, these data will be included in tabular form within Task 4 reports, as required. Base maps indicating locations of wells and surface water stations will be prepared. For reference, major contaminant source areas will also be displayed. Hydrologic and chemical data will be plotted on appropriate base maps in either symbolic or contour forms.

8.2 HISTORICAL DATA EVALUATION

Historical analytical data will be obtained from the USATHAMA Edgewater Scientific Computer Center and reviewed. Data summaries for each well will include:

- Period of record;
- Compounds determined;
- Number of detections;
- Compounds detected;
- Number of determinations; and
- Range of concentration.

Maps will be prepared indicating the areal extent of contamination in the alluvial and Denver aquifers. The format of these historical plots will be compatible with Task 4 results to allow comparison of historical and current contaminant distributions.

8.3 HISTORICAL DATA VALIDATION

Historical data will be directly compared to Task 4 results for each well sampled under the water quality monitoring program. This evaluation will compare the historical and current analytical results for selected groups of contaminants and individual parameters. The sets will be summarized on a well by well basis, indicating whether parameters were detected, undetected or not analyzed. These data summaries will allow identification of discrepancies between historical and Task 4 analytical

results, and will direct selection of wells for third and forth quarter monitoring programs.

8.4 GEOLOGIC EVALUATION

Existing RMA geologic information will be compiled and evaluated in order to provide a basis for subsequent interpretive tasks. Well and boring records will be summarized to provide surface elevation, bedrock elevation, alluvial sand and gravel thicknesses and bedrock type. These parameters will be entered into a computer data base to allow manipulation and generation of bedrock surface, geologic subcrop, isopach, and saturated thickness maps.

Bedrock stratigraphy will be evaluated by means of stratigraphic sections constructed along parallel sets of lines oriented NW-SE and NE-SW. Major fault and fracture patterns will also be delineated. Completion intervals for the wells sampled during Task 4 will be indicated on these cross sections, providing detailed hydrogeologic support for future interpretive efforts.

BIBLIOGRAPHY

Berkowitz. 1982. Problem Definition Study on Selected Chemicals. Volume IV. Site Specific Evaluation of Selected Organic Pollutants at Rocky Mountain Arsenal, Final Report. A.D. Little, Inc., Cambridge, Ma. DAMD 17-77-C-7037.

Broughton, J.D., W.L. Miller, and G.B. Mitchell. 1979. Geology and Ground Water Definition Base A Area, Rocky Mountain Arsenal, Commerce City, Colorado.

Cogley, D.R. and W. Foy. 1978. Readily Available Data on 169 Compounds Associated with Operations at Rocky Mountain and Pine Bluff Arsenals. Supported by: USMRDC, Frederick, Md., and USATHAMA, Aberdeen Proving Ground, Md. Walden Division of Abcor, Inc., Wilmington, Mass. Contract No. DAMD17-077-C-7050.

Costa, J.E. and S.W. Bilodeau. 1982. Geology of Denver, Colorado, U.S.A. Colorado Geological Survey, Department of Natural Resources.

D.P. Associates, Inc. June 1985. Section Plots and Well Summaries. Rocky Mountain Arsenal.

Edgewood. 1976. Decontamination Technology Research and Development Program for Installation Restoration at RMA, Commerce City, Colorado. Edgewood Arsenal RIC 81324R28.

Environmental Science and Engineering. 1985. Rocky Mountain Arsenal Section 36 Contamination Survey Technical Plan (Task 1). Prepared for: USATHAMA. Englewood, Colorado.

Environmental Science and Engineering. 1986. Initial Screening Report. Rocky Mountain Arsenal. Prepared for: USATHAMA. Englewood, Colorado.

Kolakowski, J.E. 1979. Migration Potential of Contaminants in the Soil of Rocky Mountain Arsenal. Vol. I. Open Literature Review. Prepared for: USATHAMA. Chemical Systems Laboratory, Aberdeen Proving Ground, Md.

Kolmer, J.R. and G.A. Anderson. 1977. Installation Restoration of RMA, Part I -- Pilot Containment Operations Final Environmental Impact Statement.

May, J.H. 1982. Regional Ground Water Study of Rocky Mountain Arsenal, Colorado: Report #1, Hydrogeological Definition. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Resource Consultants, Inc. 1982. Surface Water Hydrologic Analysis Rocky Mountain Arsenal, Commerce City, Colorado.

Robson, S.G., and J.C. Romero. 1981. Geologic Stucture, Hydrology and Water Quality of the Denver Aquifer in the Denver Basin, Colorado. USGS and Colorado Division of Water Resources.

Rocky Mountain Arsenal. 1984. Agent Fact Sheet. SMCRM Form 357.

RMA-Contamination Control Project Management Team (RMA-CCPMT). 1983. Selection of a Contamination Control Strategy for Rocky Mountain Arsenal, 2 Volumes. USATHAMA and RMA, RIC 83326R01, G&M 155.

Rocky Mountain Arsenal. 1983. Chemical Accident and Incident Control. In: Disaster Control Plan. RMA-DCP. Commerce City, Colorado.

Rocky Mountain Arsenal. 1983. Master Accident Prevention Safety Program. RMAP 385-1. Commerce City, Colorado.

Romero, J.C. 1976. Report on the Ground Water Resources of the Bedrock Aquifer of the Denver Basin, Colorado. Colorado Department of Natural Resources.

Rosenblatt, et al., 1975. Problem Definition Study on Potential Environmental Pollutants: Vol. I, Toxicology and Ecological Hazards of 16 Substances at Rocky Mountain Arsenal, and Vol. II, Physical, Chemical, Toxicological, and Biological Properties of 16 Substances. USAMBRDL, Fort Detrick, Md. Technical Reports 7508 and 7509.

Spanggord, R.J., Chou, T-W., Mabey, W.R. 1979. Studies of Environmental Fates of DIMP and DCPD. Supported by: USARMRDC. Frederick, Md. SRI International, Menlo Park, Ca.

Stollar, R.L. and F. van der Leeden. 1981. Evaluation of the Hydrogeologic System and Contamination Migration Patterns, Rocky Mountain Arsenal, Final Report. Geraghty & Miller, Inc.

Tucker, W.A., Gensheimer, G.J., and Dickinson, R.F. 1984. Coping with Uncertainty in Evaluating Alternative Remedial Actions. The 5th National Conference on Management of Uncontrolled Hazardous Waste Sites, Nov. 7-9, HMCRI, Washington, D.C.

U.S. Army Medical Bioengineering Research and Development Laboratory. 1984. The Preliminary Pollutant Limit Value Approach: Procedures and Data Base. Prepared for USAE Waterways Experiment Station, Vicksburg, Mississippi. U.S. Army Medical Research and Development Command, Fort Detrick, Frederick Maryland.

BIBLIOGRAPHY
(Continued, Page 3 of 3)

U.S. Army Medical and Bioengineering Research and Development. 1976. Problem Definition Studies on Potential Environmental Pollutants. Vol. IV. Physical, Chemical, Toxicological, and Biological Properties of Benzene, Toluene, Xylenes, and p-Chlorophenyl Methyl Sulfide, Sulfoxide, and Sulfone. USAMROC. Washington, D.C. Technical Report 7605.

U.S. Army Toxic and Hazardous Materials Agency. 1983. Geotechnical Requirements for Drilling, Monitor Wells, Data Aquisition, and Reports. Aberdeen Prooving Ground. Maryland.

U.S. Department of the Army and Air Force. 1963. Military Chemistry and Chemical Agents. TM3-215 and AFM355-7.

U.S. Environmental Protection Agency. 1982. Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater. Environmental Monitoring and Support Laboratory, Office of Research and Development, Cincinnati, Ohio. EPA-600/4-82-057.

U.S. Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory, Office of Research and Development, Cincinnati, Ohio. EPA-600/4-79-020.

U.S. Environmental Protection Agency. 1984. Memorandum from William Hedeman, Director of Office of Emergency and Remedial Response, and Gene Lucero, Director of Office of Waste Programs Enforcement, to Waste Management Division Directors, Regions I-X. Subject: Preparation of Records of Decision for Fund Financed and Responsible Party Remedial Actions.

U.S. Geologic Survey, Office of Water Data Aquisitin. 1977. National Handbook of Recommended Methods for Water - Data Aquisition.

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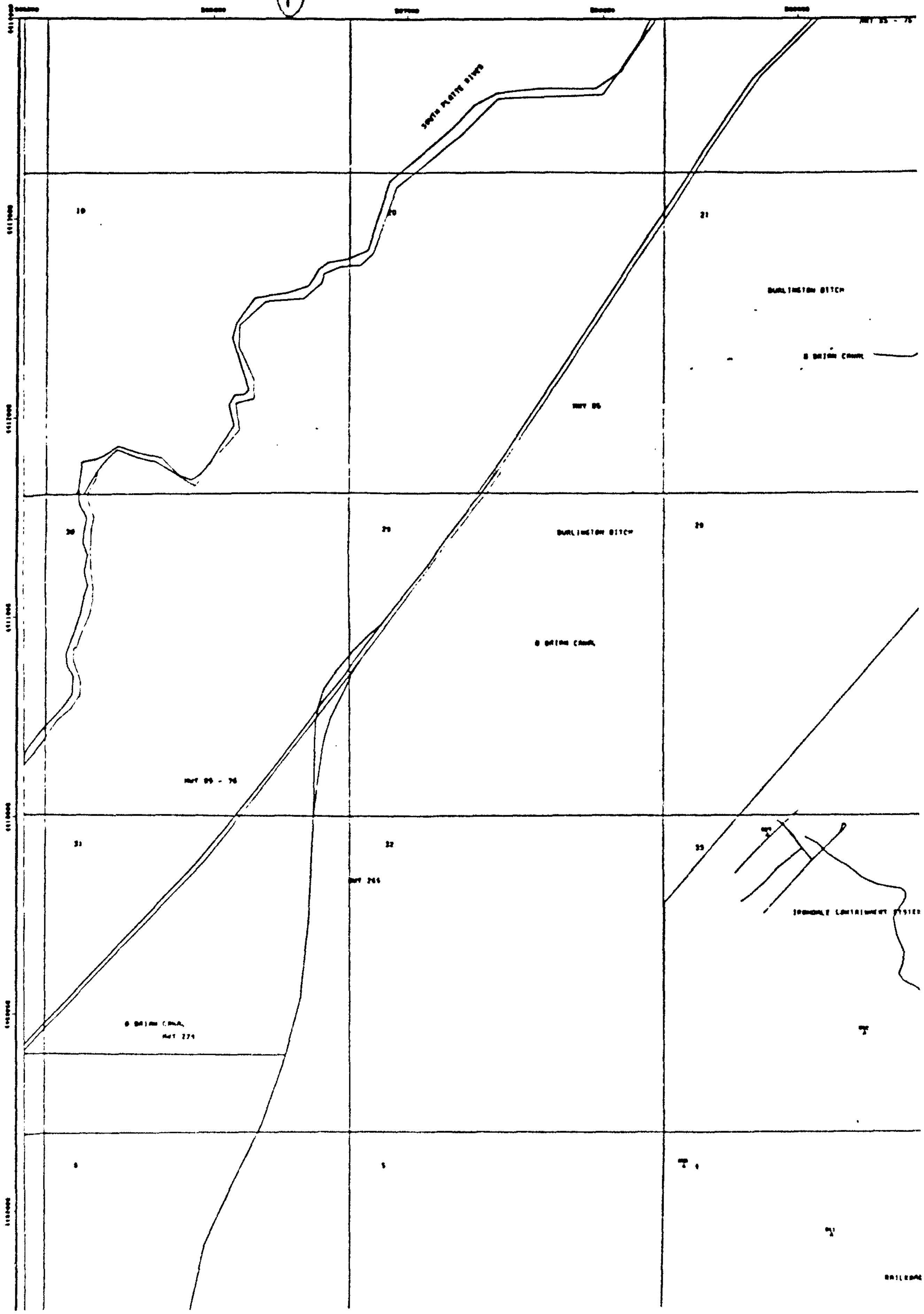

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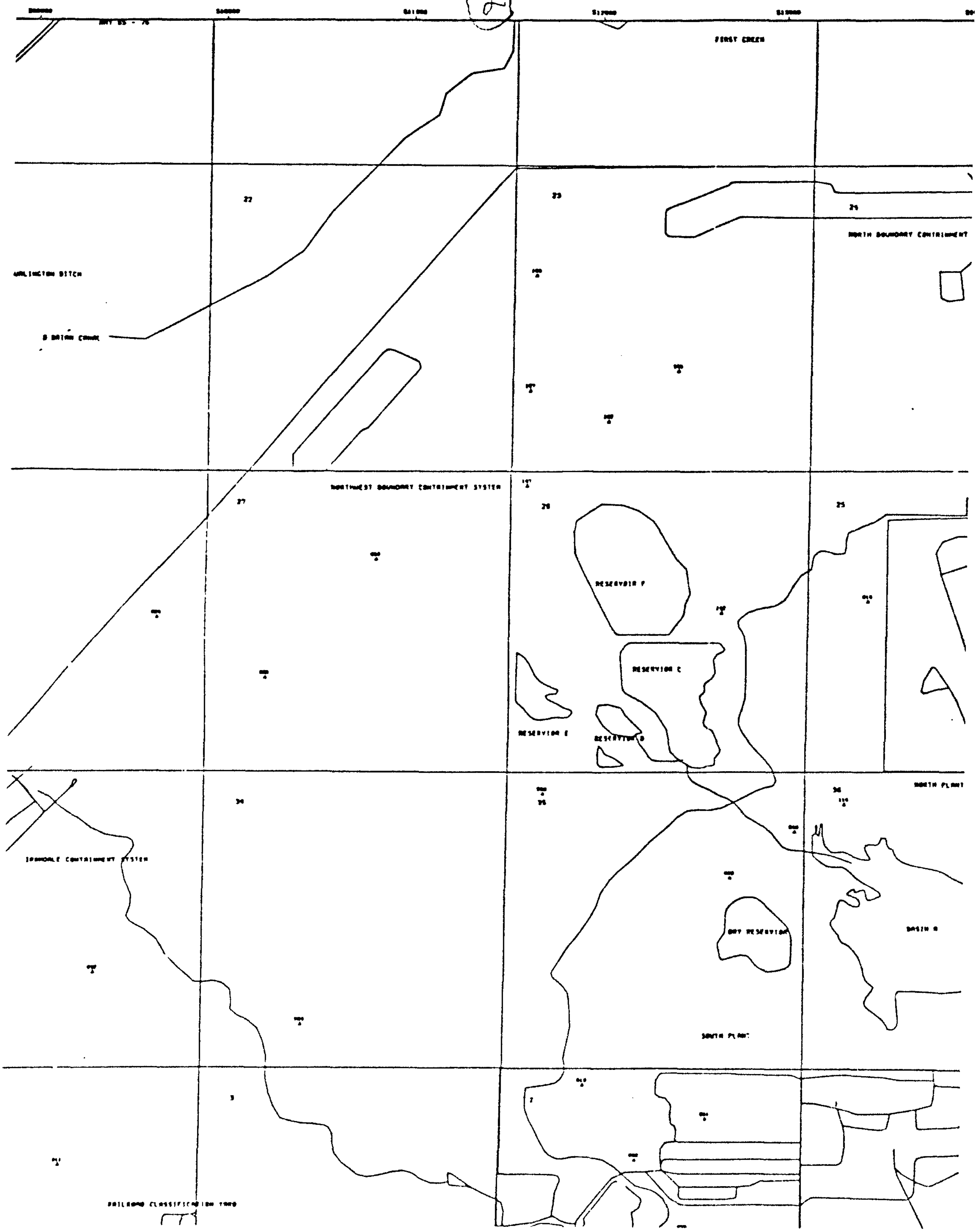

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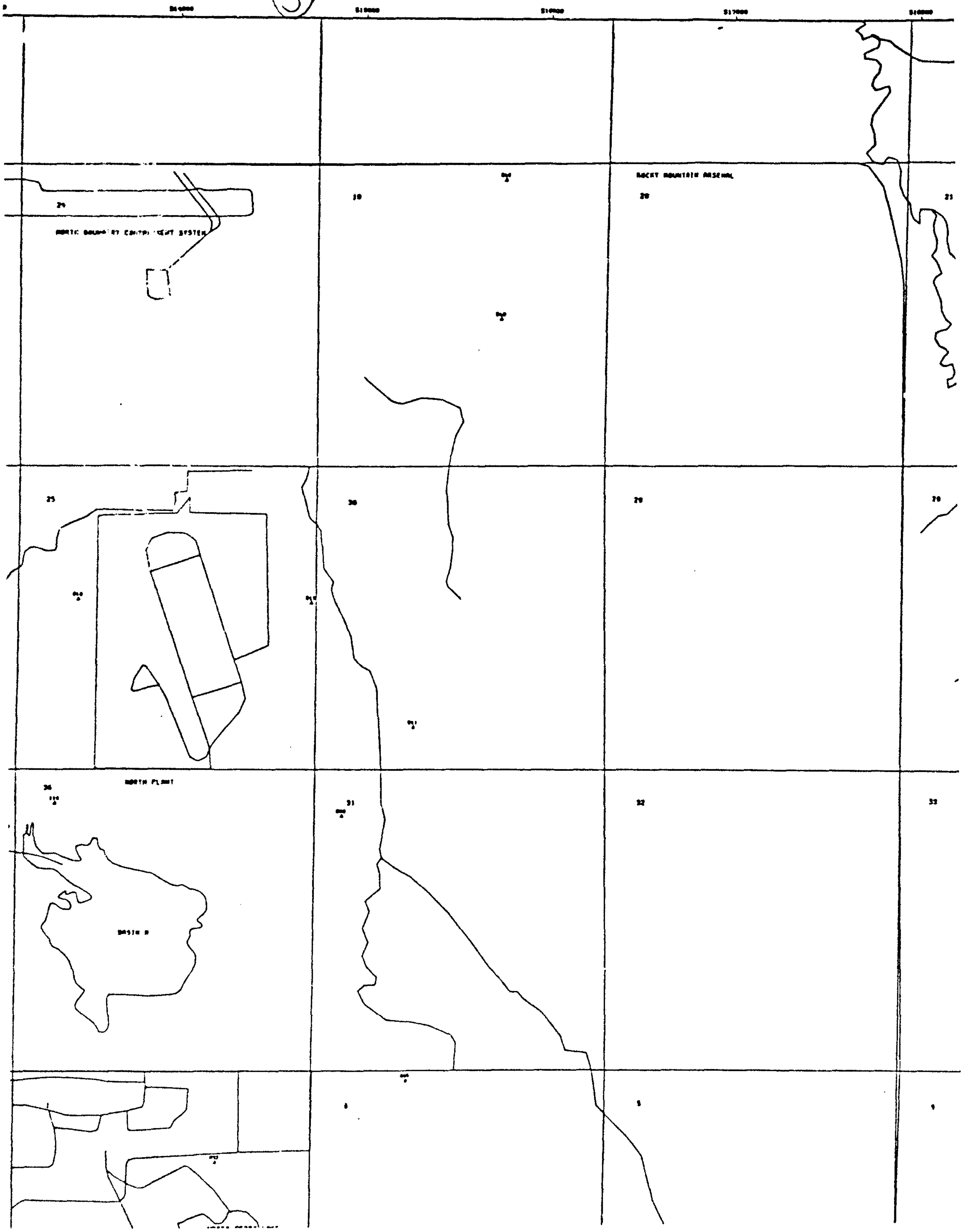
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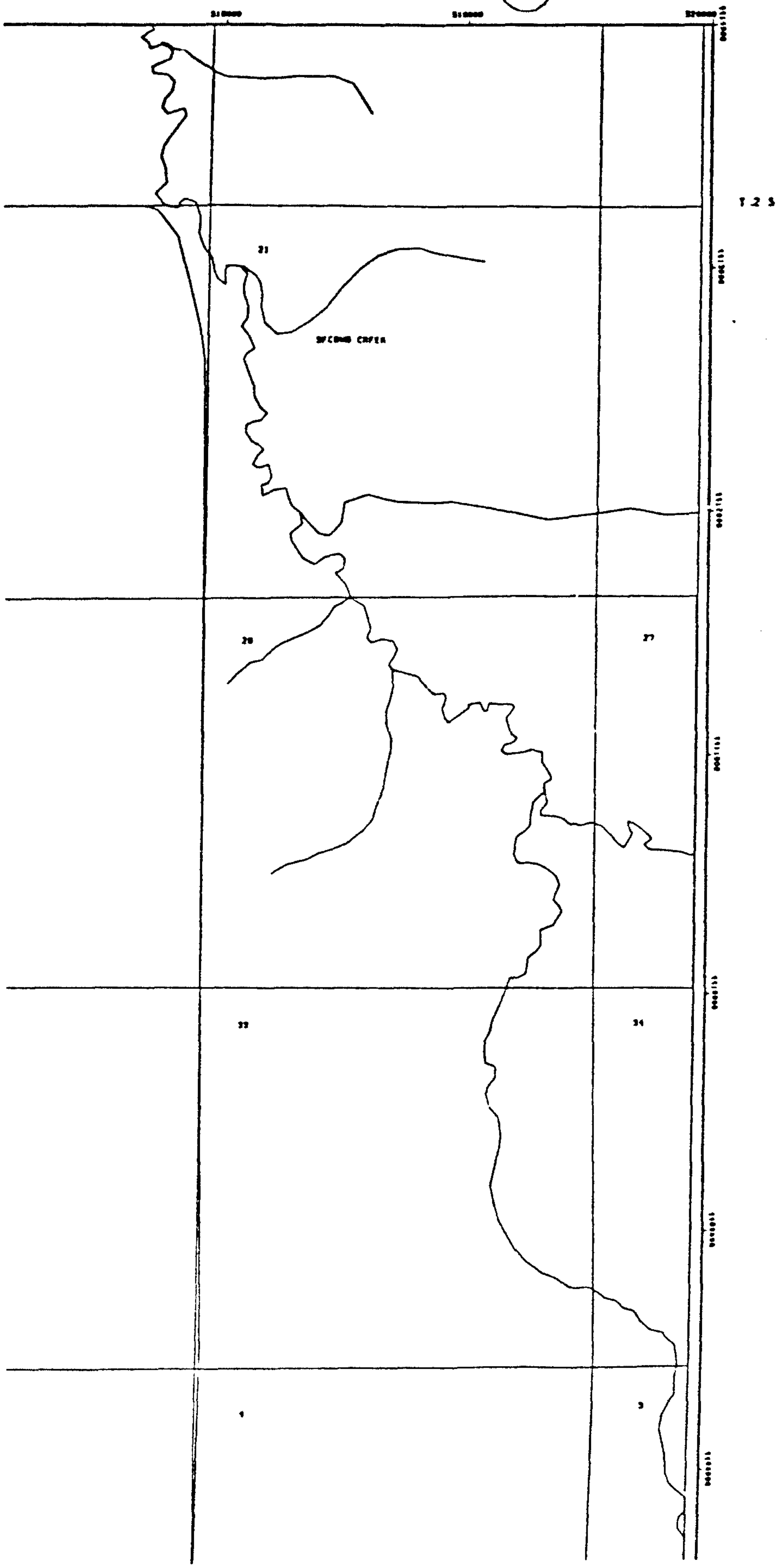

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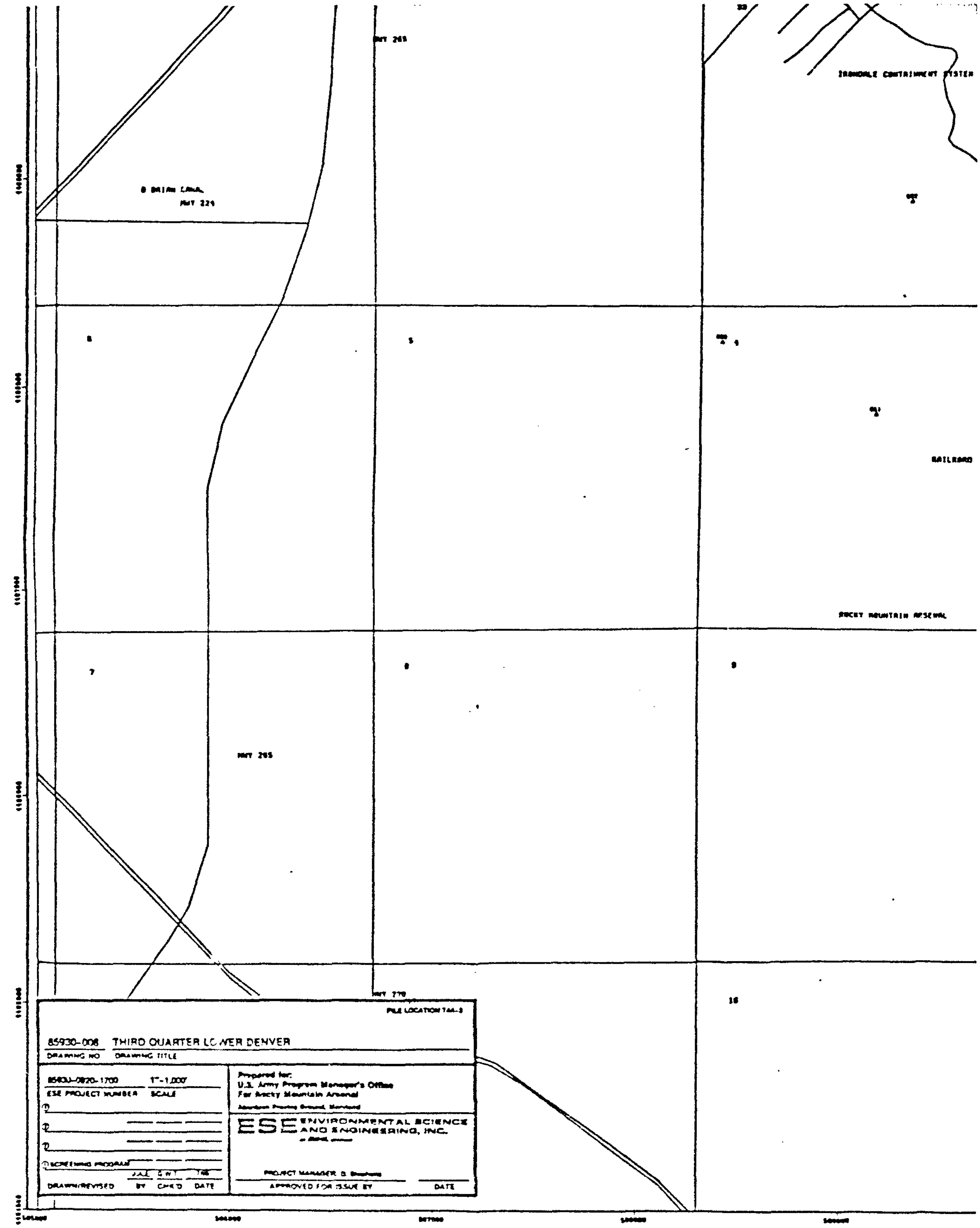

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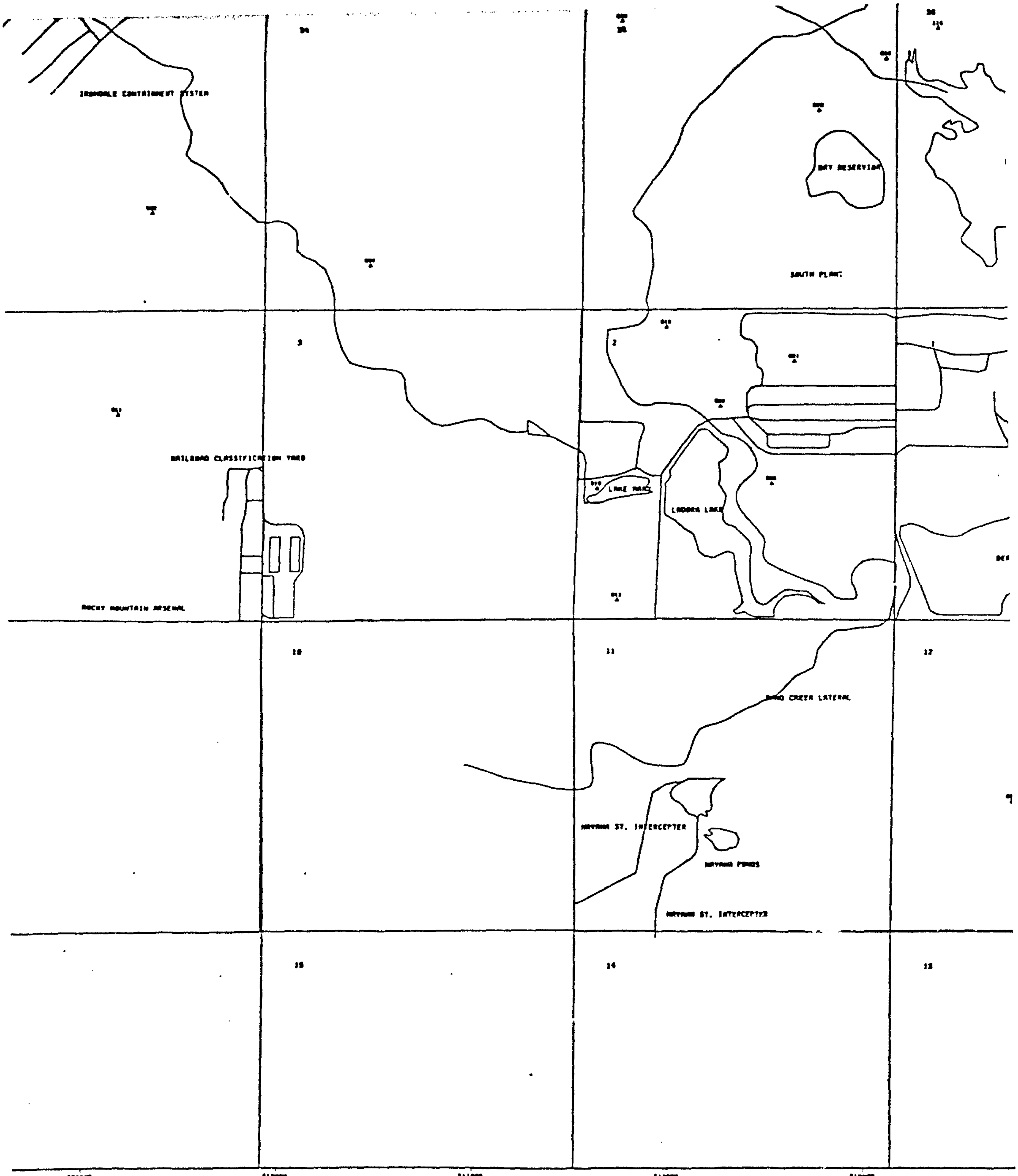
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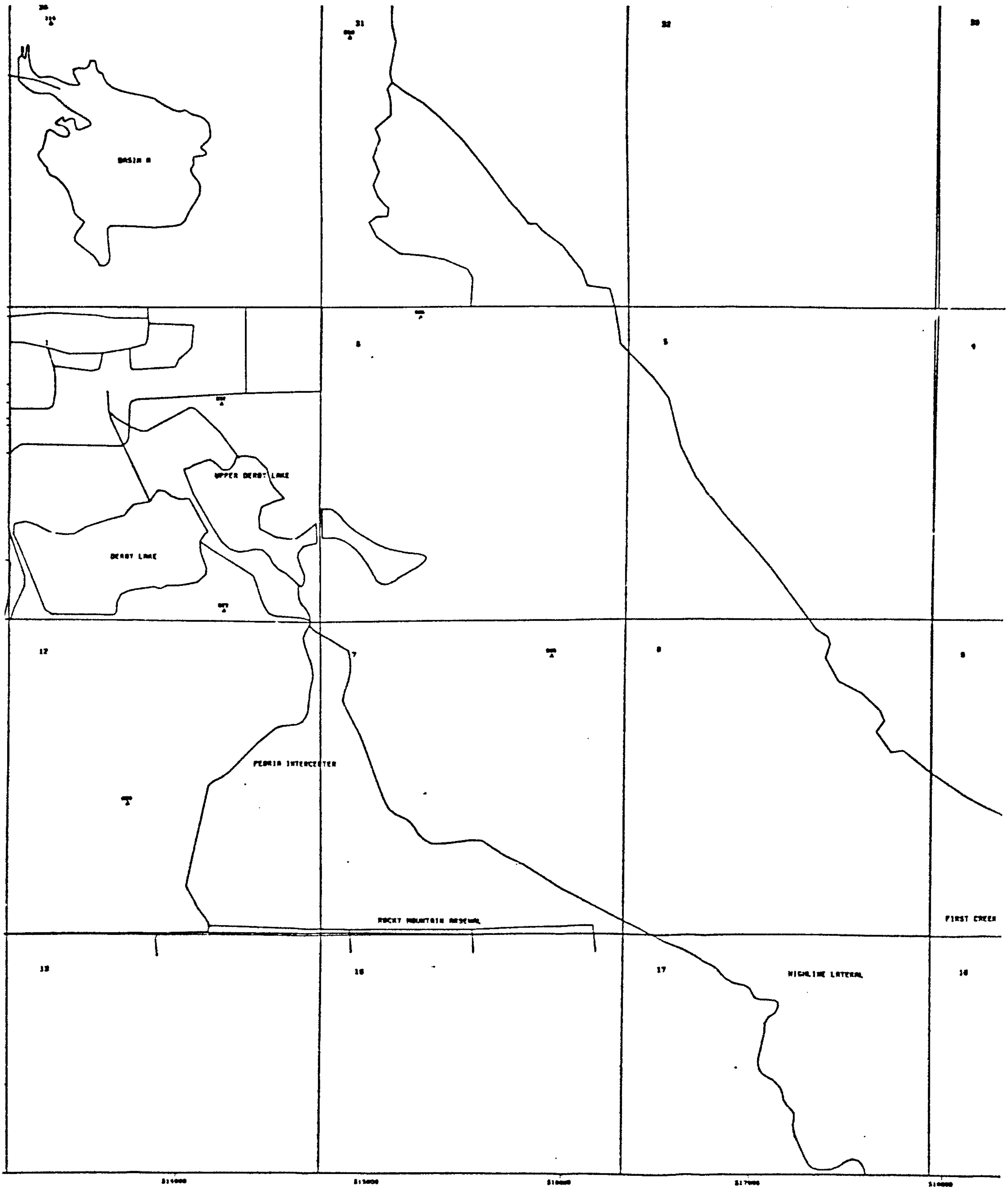

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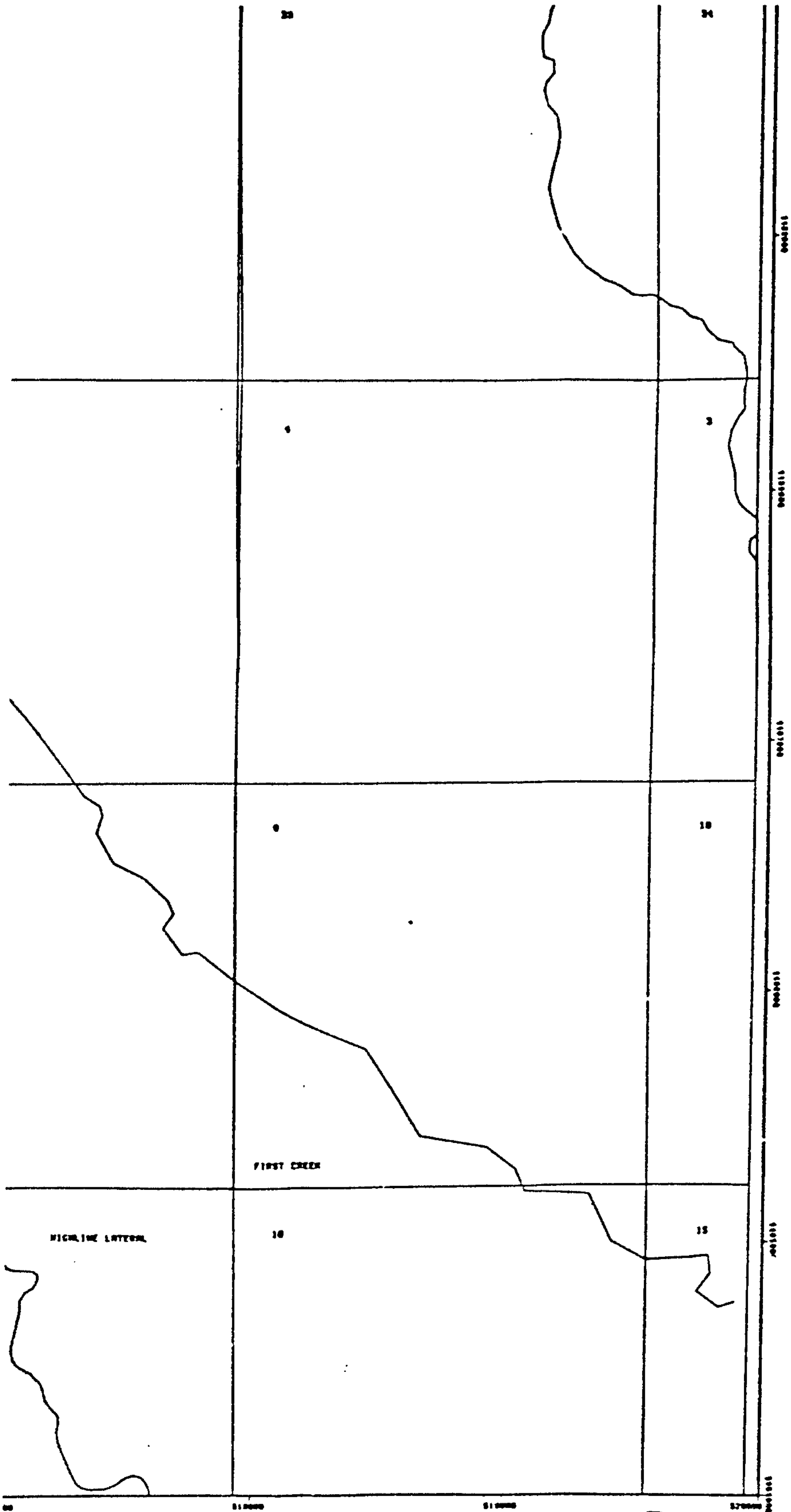

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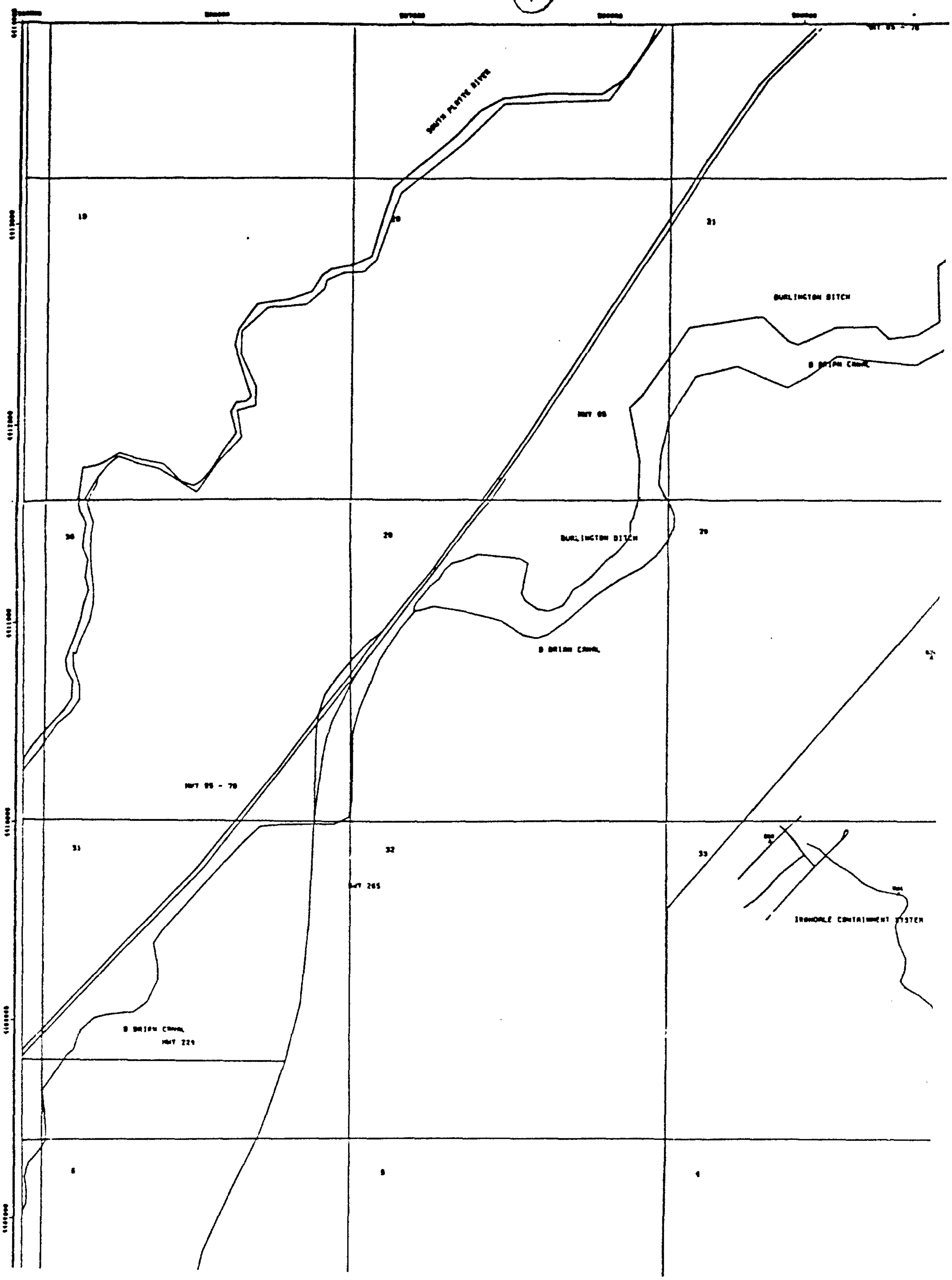
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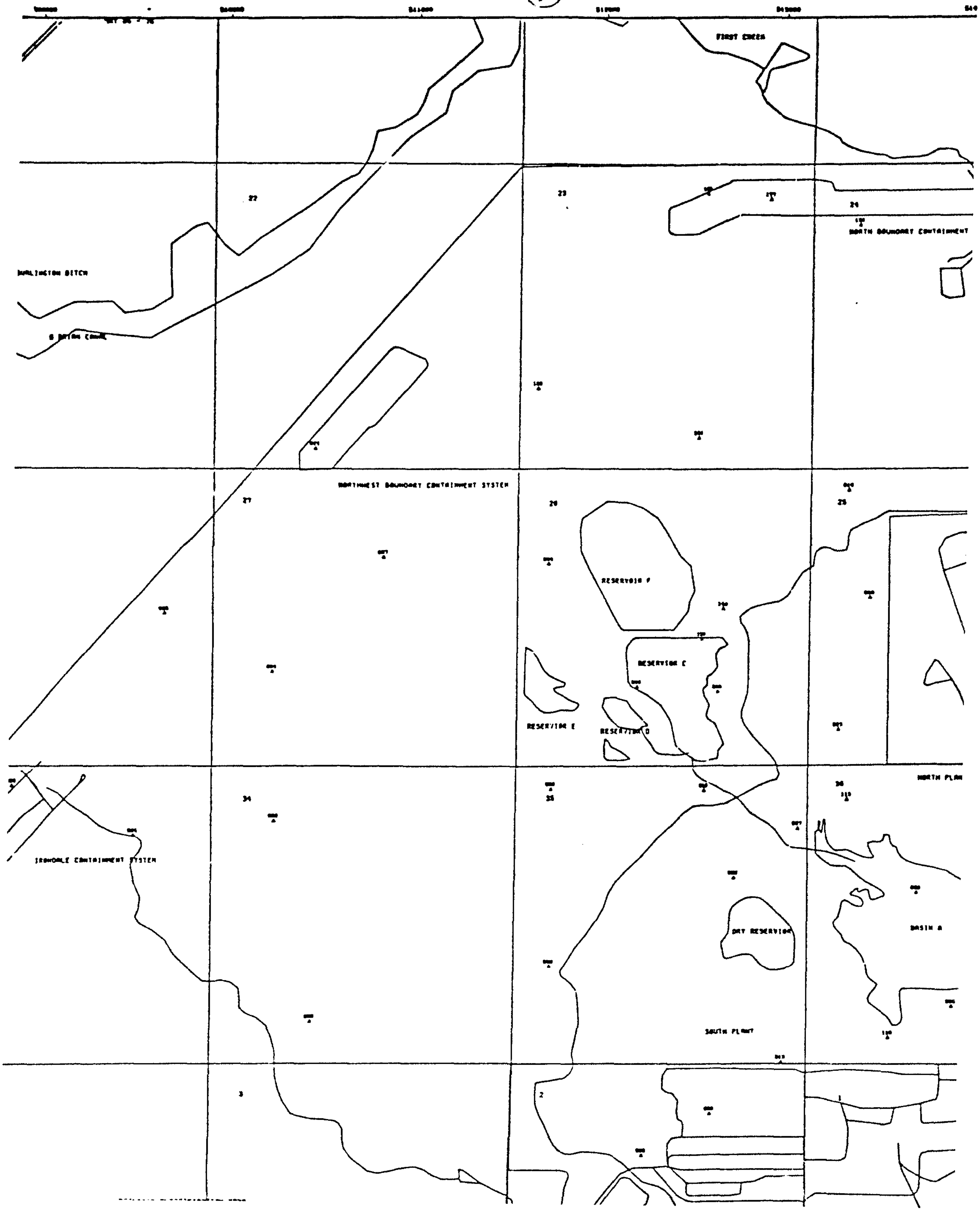

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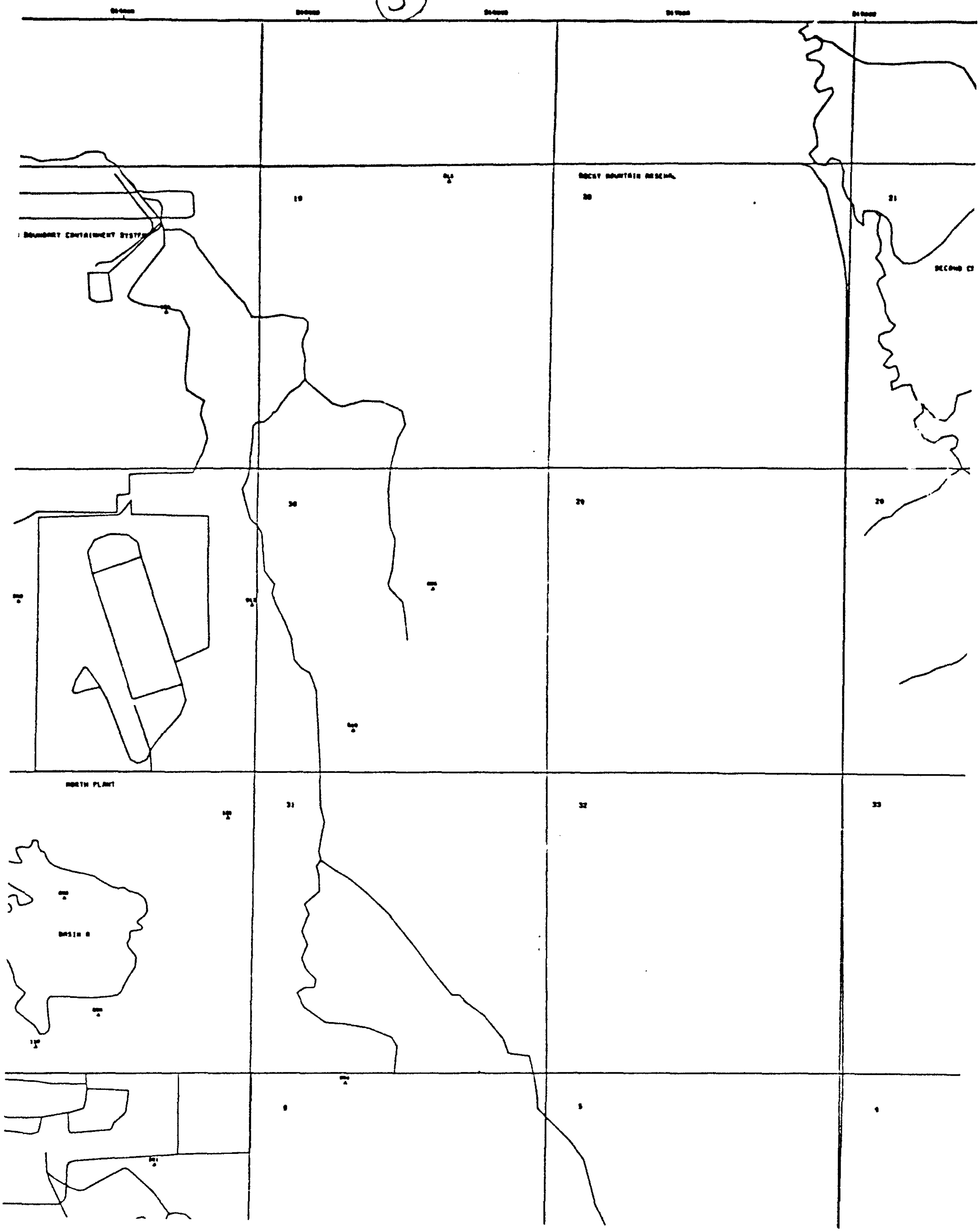

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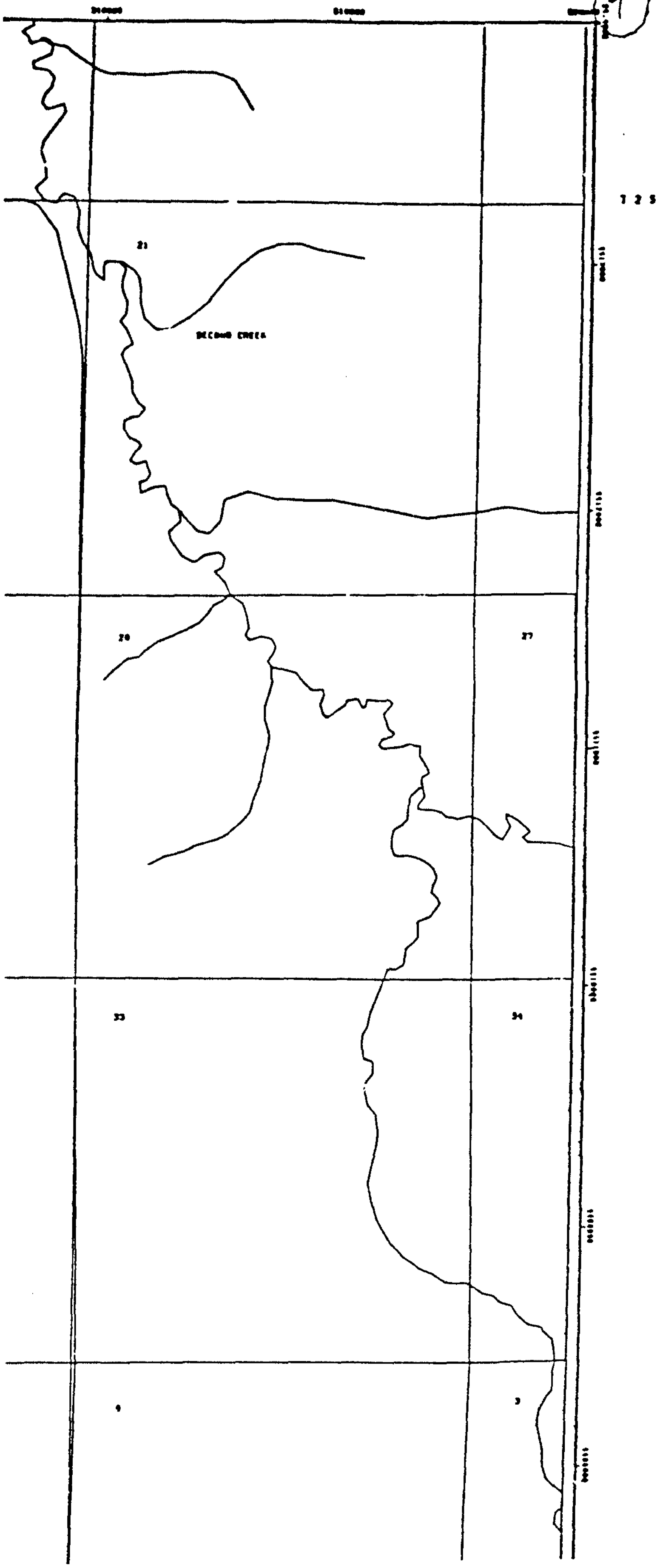

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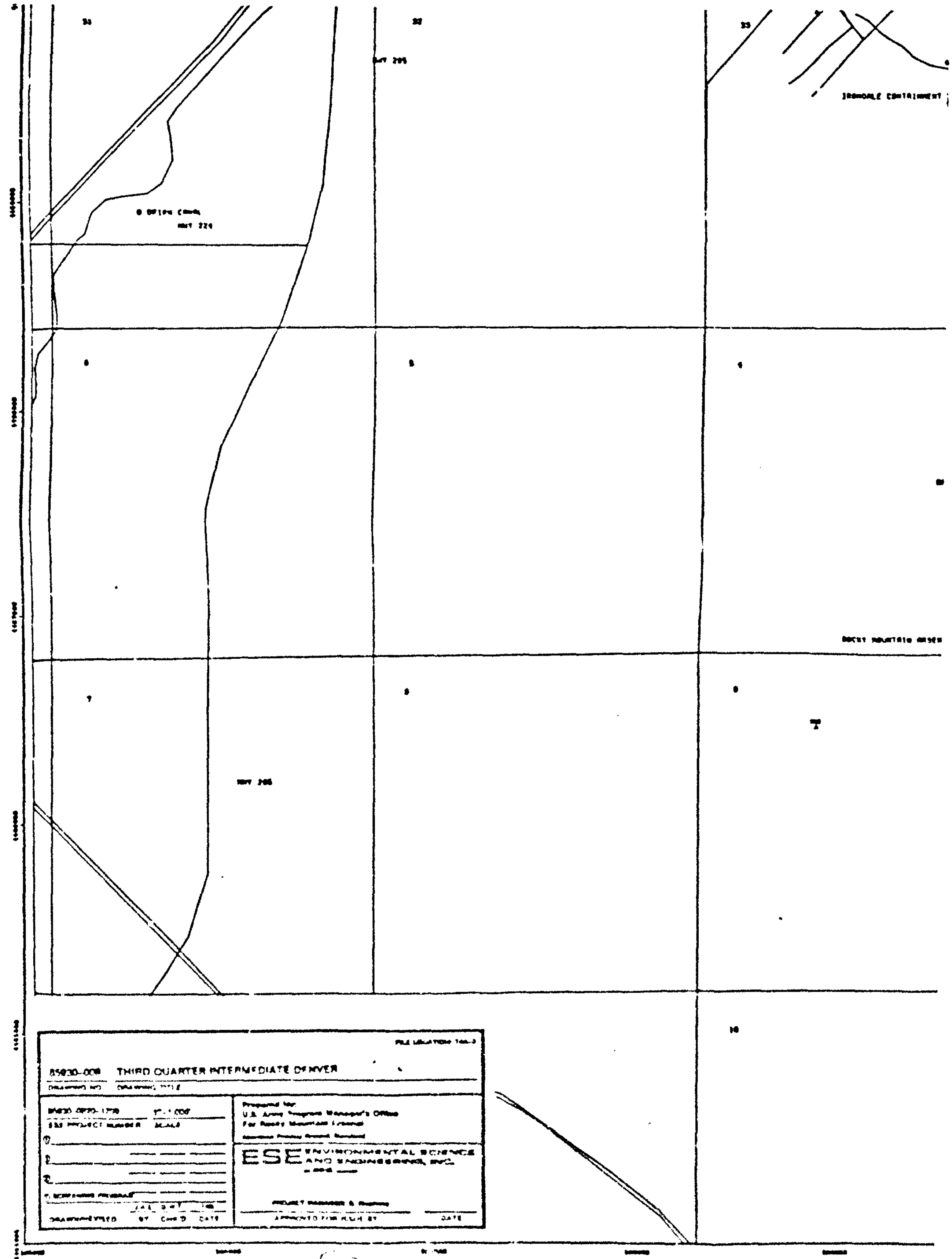

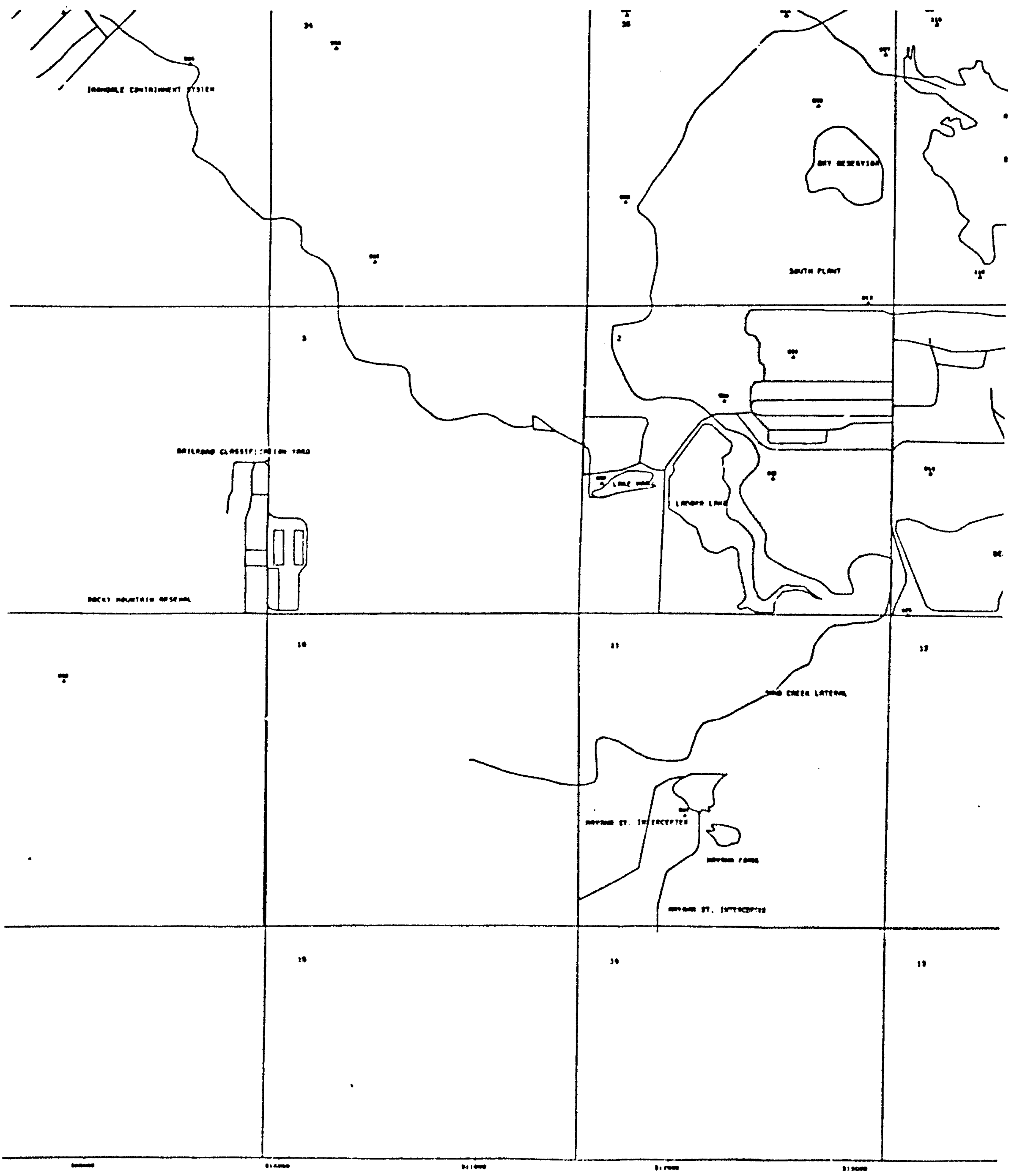

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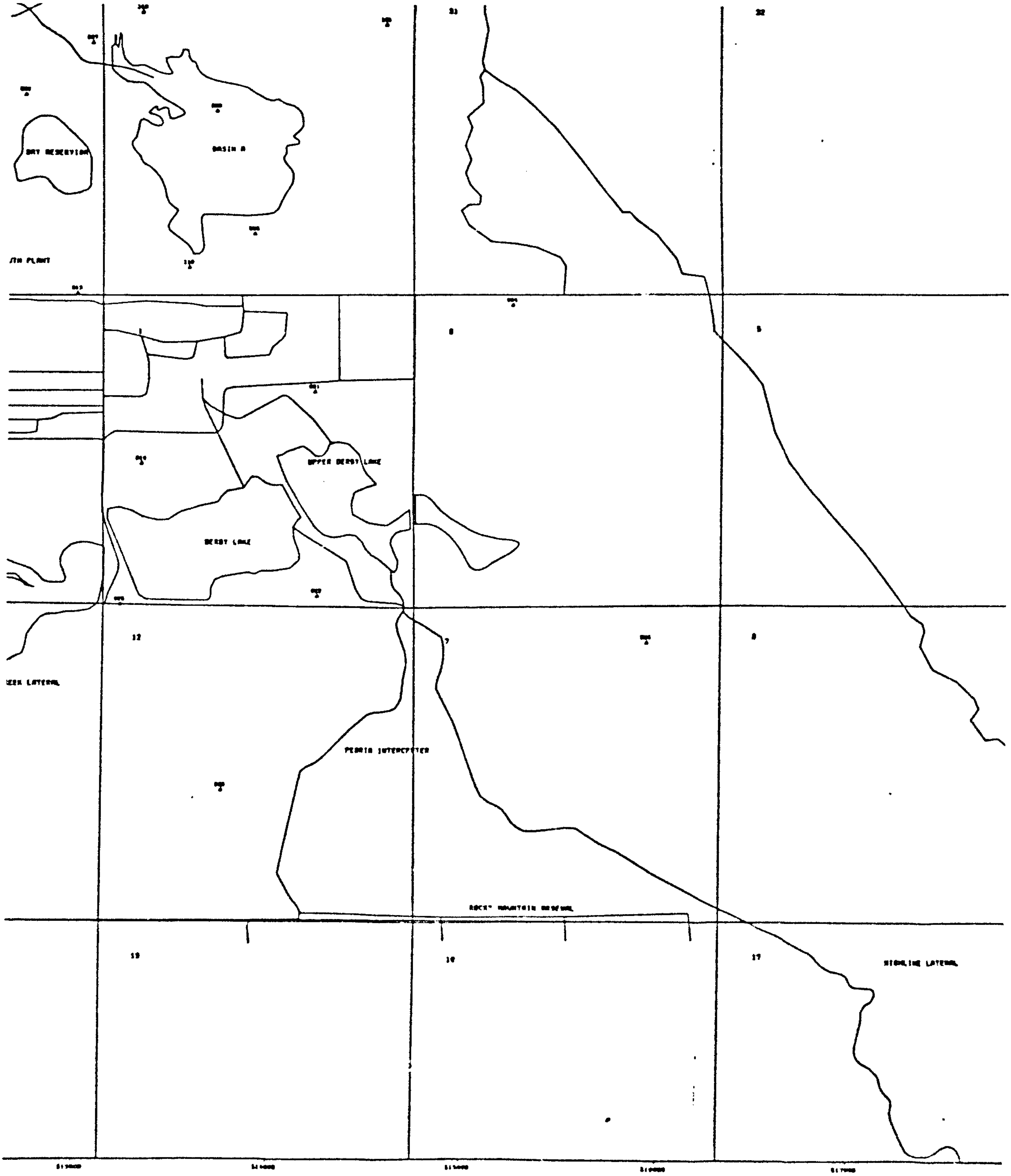

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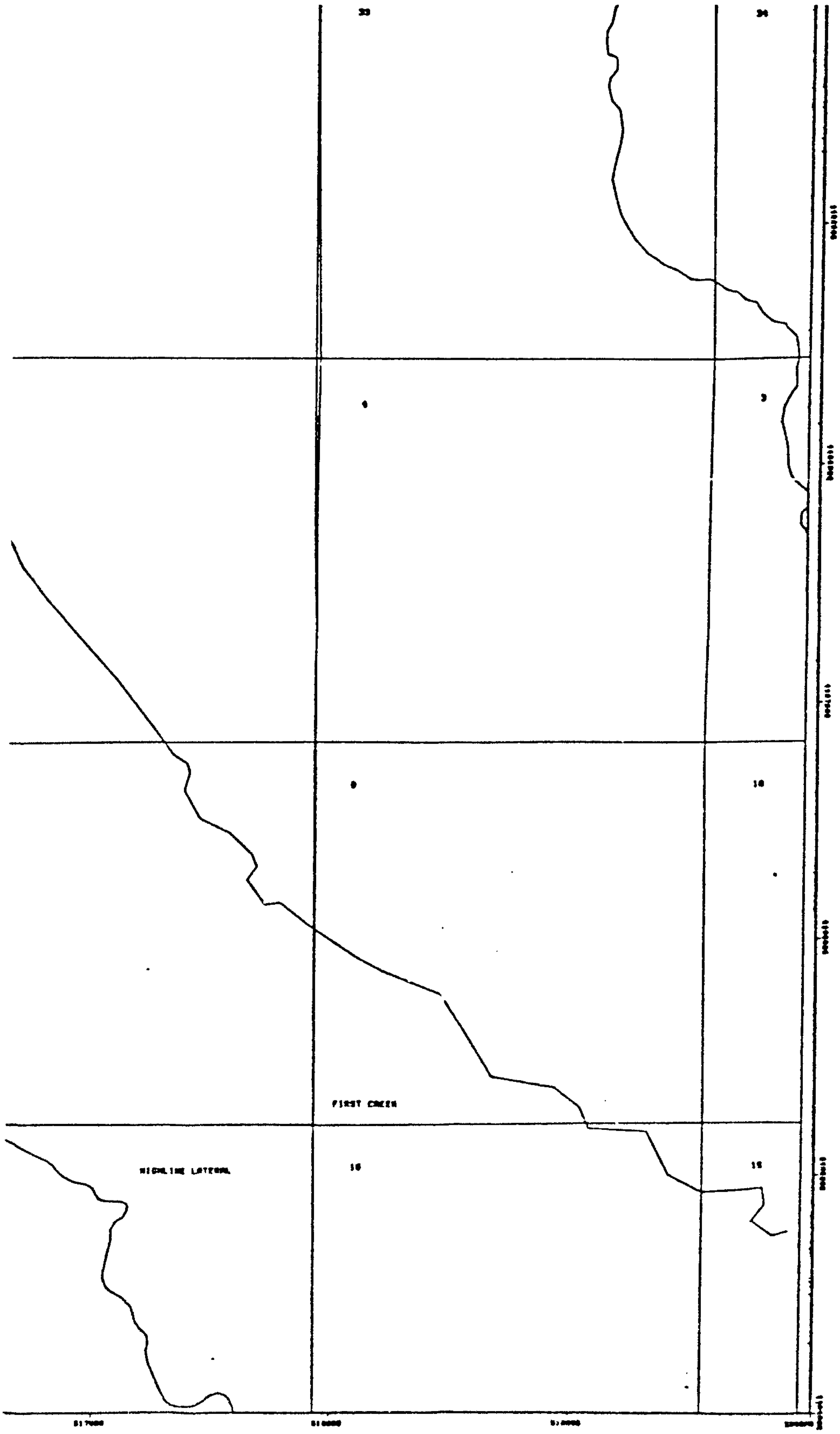
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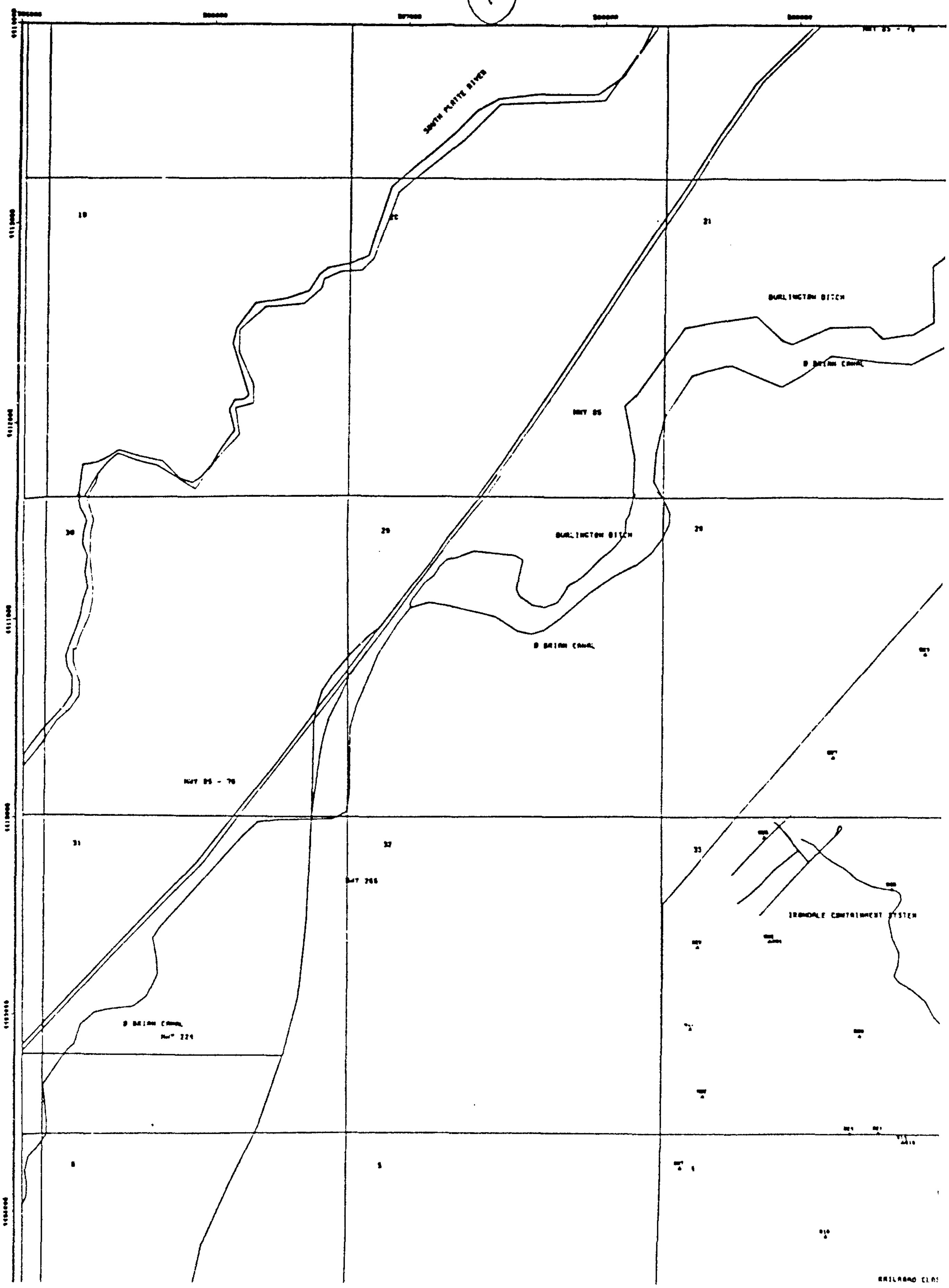

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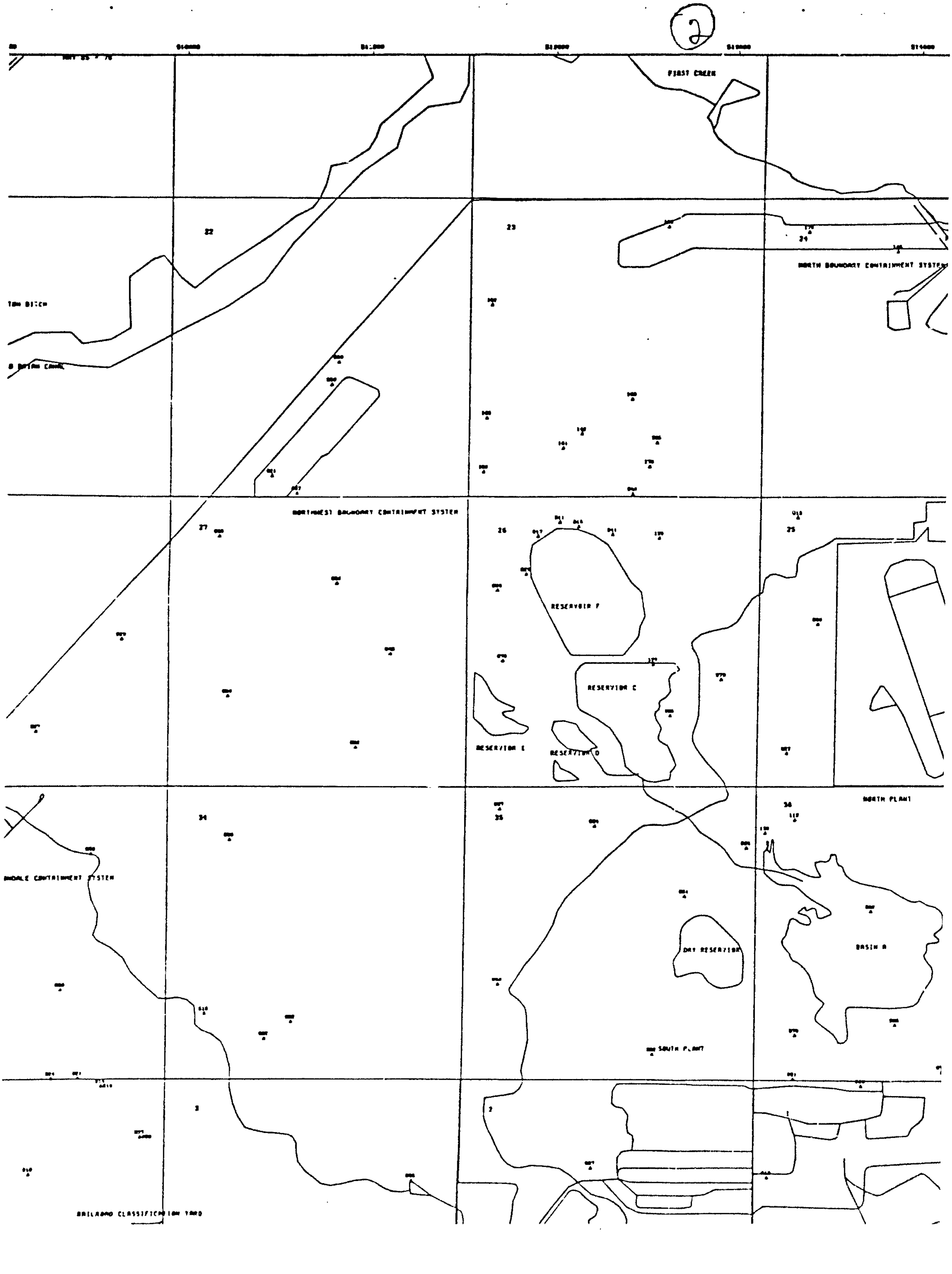

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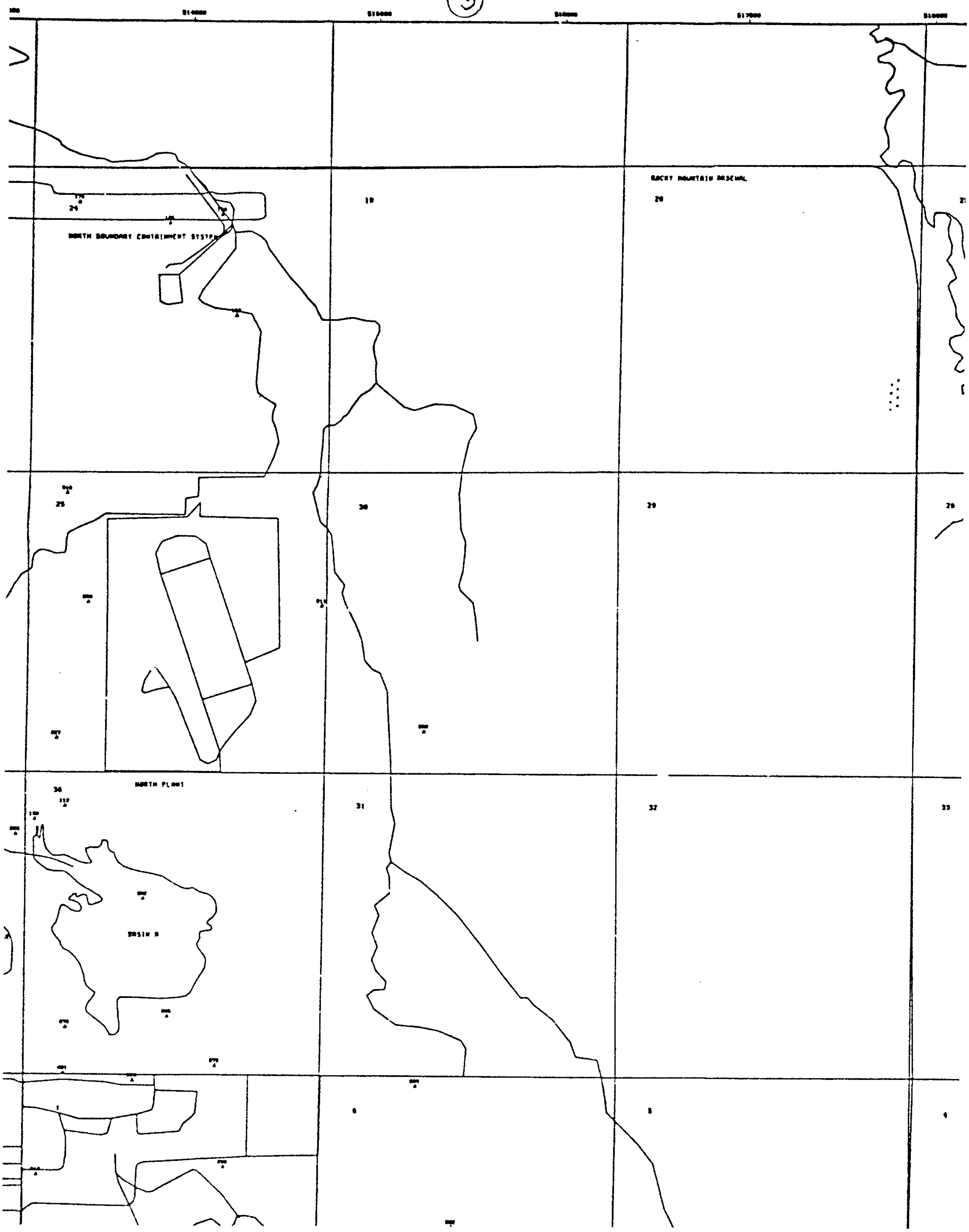
RESERVIOR E
RESERVIOR D
NORTH PLANT
BASIN A
DRY RESERVIOR
SOUTH PLANT
22
23
24
27
26
25
34
35
36
3
2
1

3



514000
517000
ROCKY MOUNTAIN ARSENAL
NORTH BOUNDARY CONTAINMENT SYSTEM
NORTH PLANT
BASIN A
24
19
20
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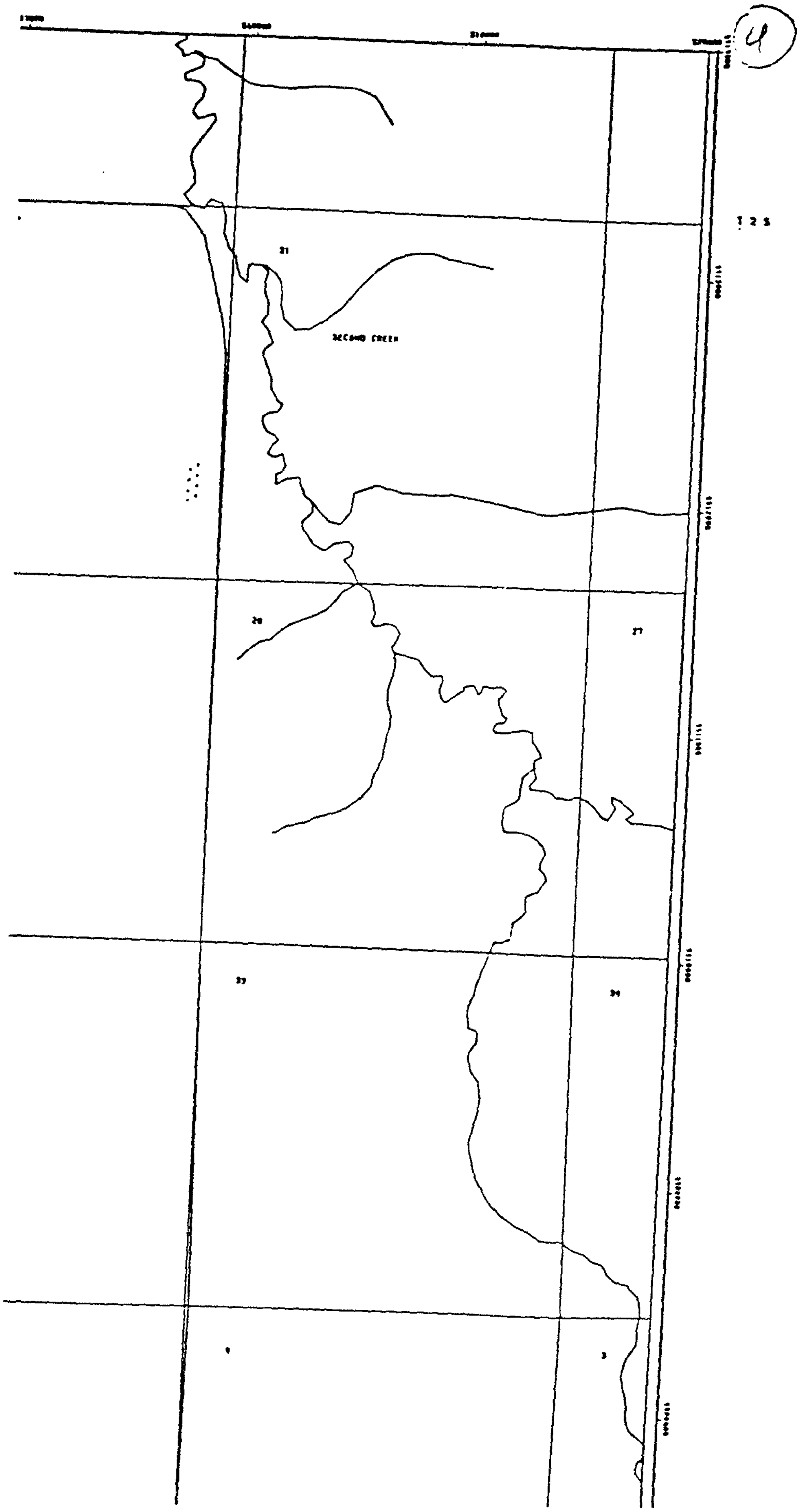
29
28
36
31
32
33
6
5
4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21
SECOND CREEK
28
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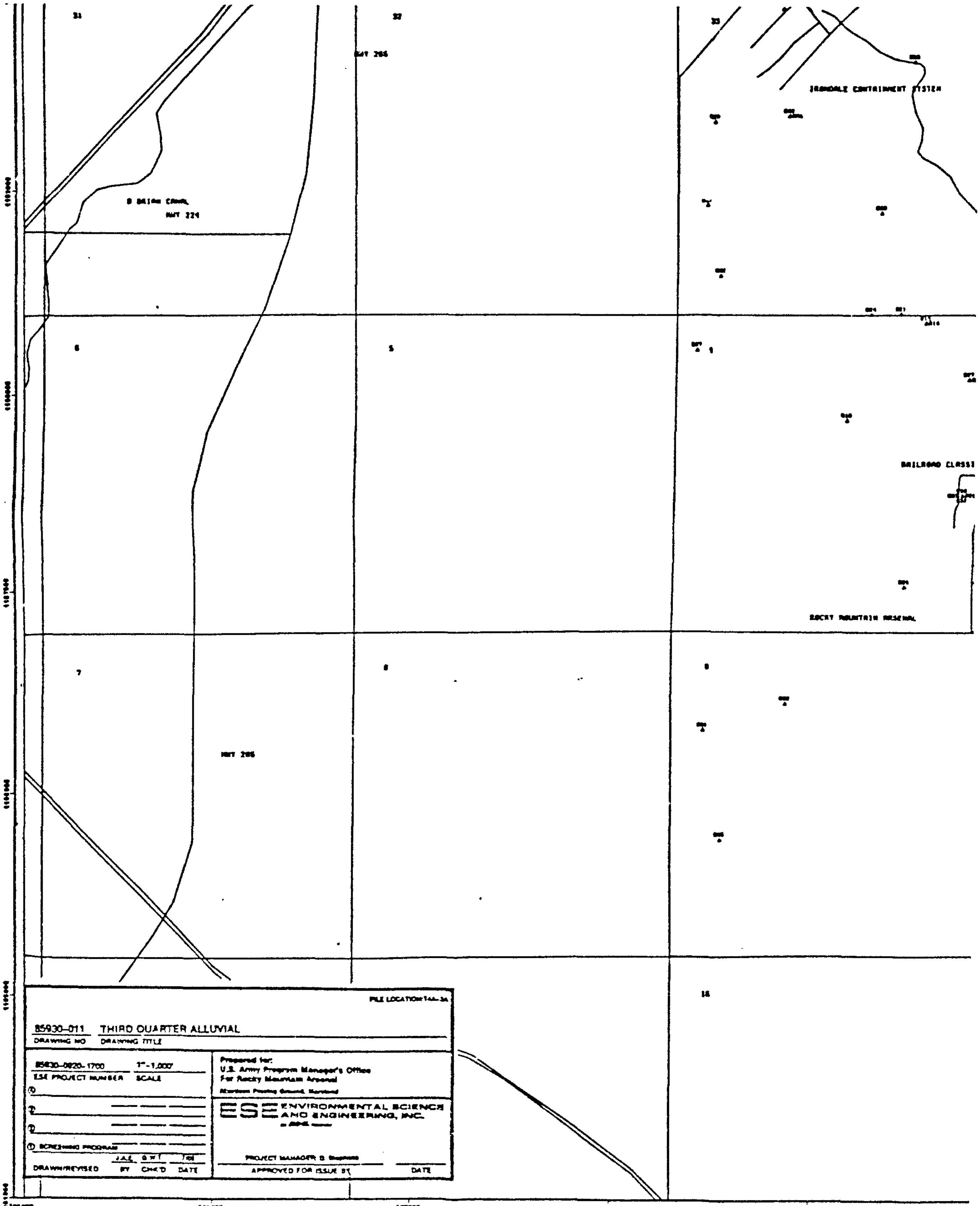


85930-011 THIRD QUARTER ALLUVIAL

DRAWING NO DRAWING TITLE

85930-0820-1700 1"=1,000'

ESE PROJECT NUMBER SCALE

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

ESE ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.

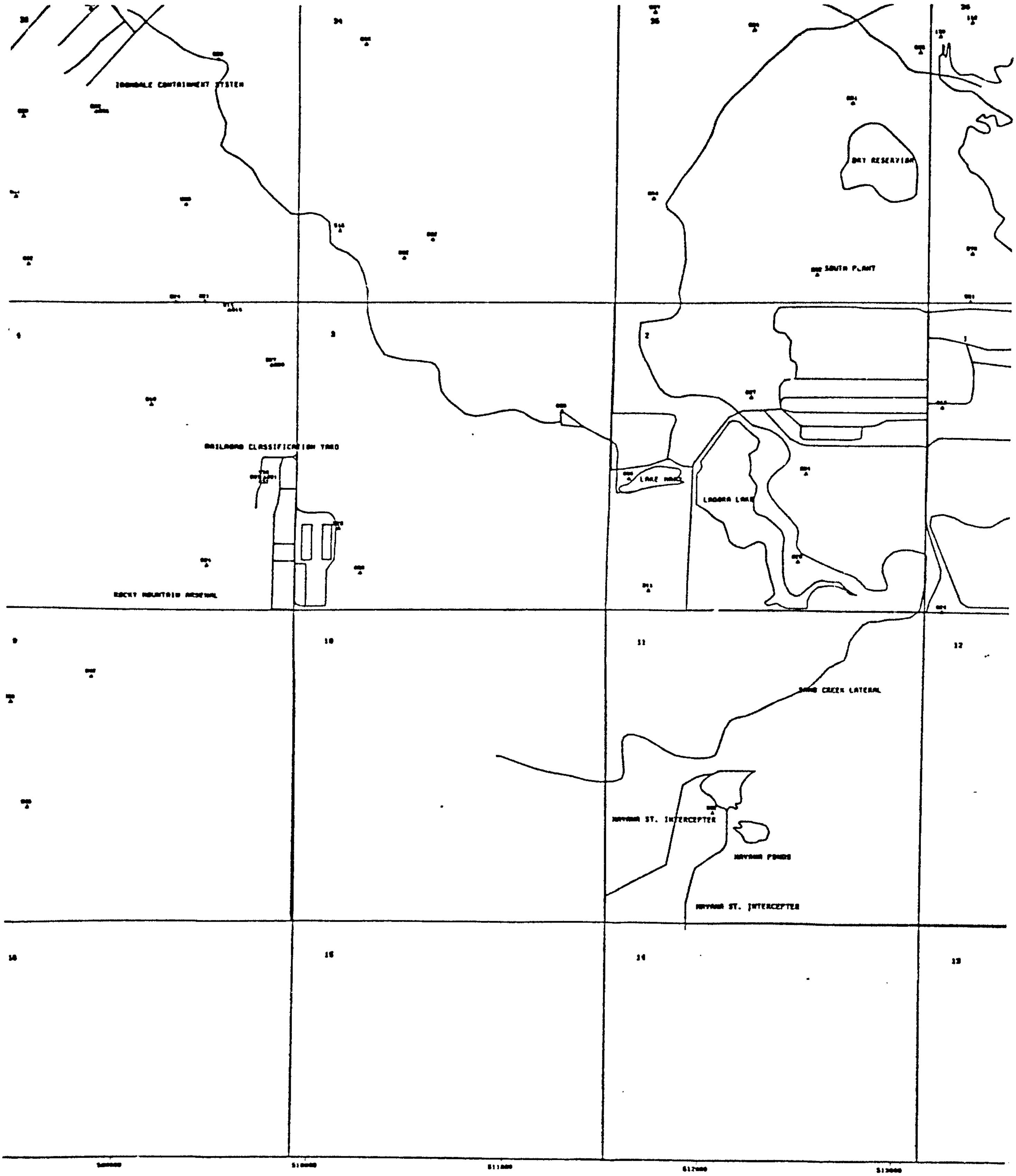
(1) SCREENING PROGRAM

DRAWN/REVISED BY CHK'D DATE

PROJECT MANAGER

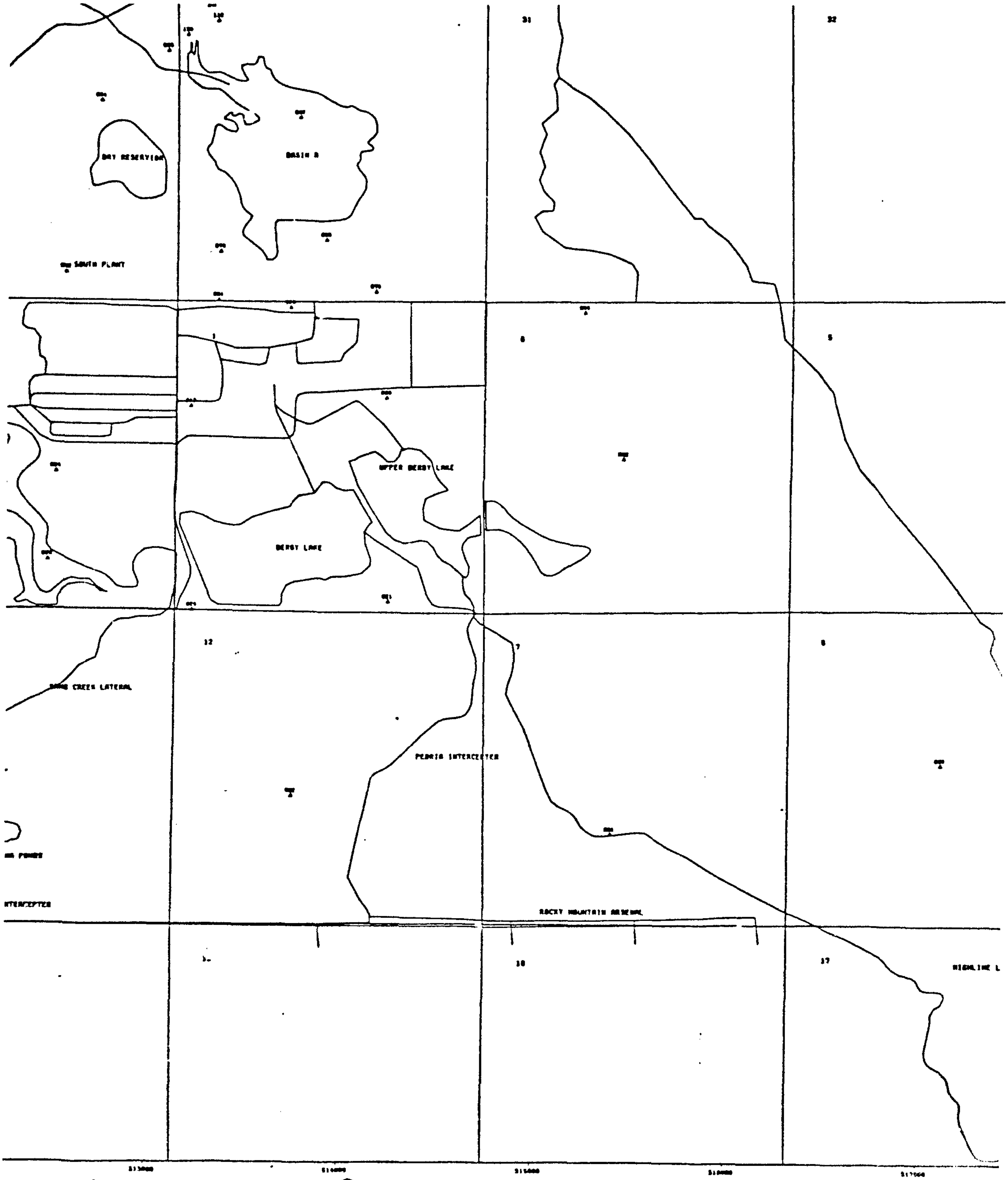
APPROVED FOR ISSUE BY DATE

5

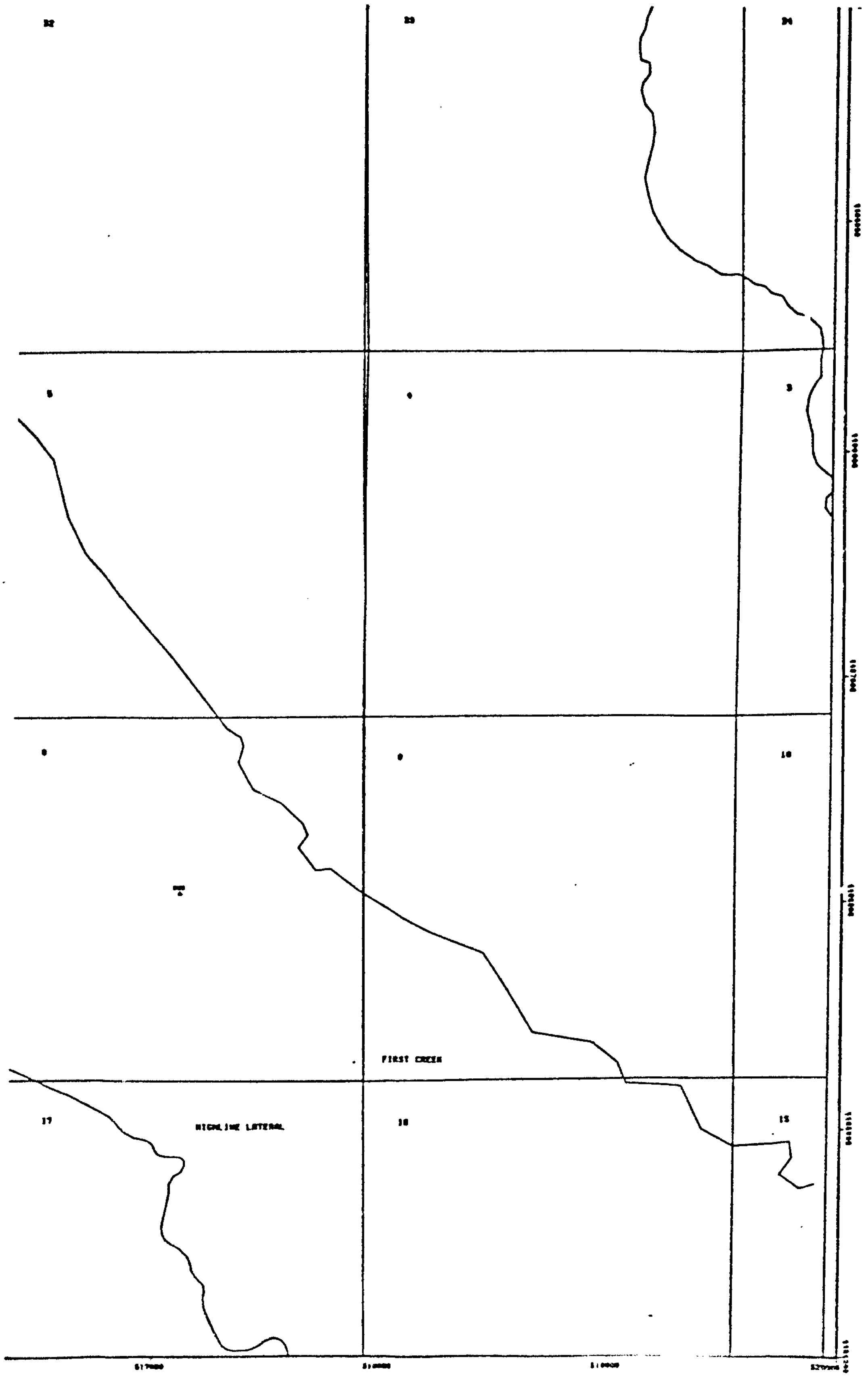


IRONDALE CONTAINMENT SYSTEM
SOUTH PLANT
RAILROAD CLASSIFICATION YARD
LAKE MARY
LADORA LAKE
ROCKY MOUNTAIN ARSENAL
SAND CREEK LATERAL
HAVANA ST. INTERCEPTER
HAVANA PONDS
HAVANA ST. INTERCEPTER

6



31
32
BASIN A
DRY RESERVOIR
SOUTH PLANT
6
5
UPPER DERBY LAKE
DERBY LAKE
12
7
8
SAND CREEK LATERAL
PEORIA INTERCEPTER
ROCKY MOUNTAIN ARSENAL
18
17
HIGHLINE L



32
33
34
3
10
FIRST CREEK
17
HIGHLINE LATERAL
16
15